Cy No. 34

EARTH RESOURCES TECHNOLOGY SATELLITE
FINAL REPORT

14. GROUND DATA HANDLING SYSTEM DESIGN

PREPARED FOR

GODDARD SPACE FLIGHT CENTER
NATIONAL AERONAUTICS
AND SPACE ADMINISTRATION

UNDER CONTRACT NAS5-11260

TRW SYSTEMS GROUP

IBM FEDERAL SYSTEMS DIVISION

Itek OPTICAL SYSTEMS DIVISION

EARTH RESOURCES TECHNOLOGY SATELLITE

FINAL REPORT

Volume 14. Ground Data Handling System Design

April 17, 1970

prepared for

National Aeronautics and Space Administration
Goddard Space Flight Center

Contract NAS5-11260
item 5a

TRW Systems Group
One Space Park · Redondo Beach
Los Angeles County
California 90278

THE FOLLOWING VOLUMES CONSTITUTE TRW'S PROPOSAL FOR PHASE D OF THE ERTS PROJECT SHADING INDICATES THE FEBRUARY SUBMITTAL WHICH IS REVISED BY THE APRIL SUBMITTAL; THE UNSHADED VOLUMES ARE EITHER NEW OR ENTIRE VOLUME REVISIONS OF THE FEBRUARY SUBMITTAL.

PART I MANAGEMENT SUMMARY	CORRESPONDING SECTION PROPOSAL INSTRUCTIONS
1 Scope of the Proposal	IIC1-3
2 Management	IIC4-7
3 Contract Work Breakdown Structure	IIC4 3
4 Summary Work Breakdown Structure	IIC8a
5 Time Schedules	IIC8c
5A PERT Printouts	IIC8c
6 Summary Hardware and Manpower Listing	IIC8b, d-k
7 Schedule of Direct Labor Hours· Codes 100-300	IIC8e (3)
7 Schedule of Direct Labor Hours: Codes 400-500	IIC8e (3)
7 Schedule of Direct Labor Hours. Code 600	IIC8e (3)
8 Schedule of Materials Codes 100-500	IIC8e (3)
8 Schedule of Materials· Code 600	IIC8e (3)
9 Schedules of Travel and ODC: Codes 100-300	IIC8e (3)
9 Schedules of Travel and ODC: Codes 400-500	IIC8e (3)
9 Schedule of Travel and ODC Code 600	IIC8e (3)
10 Summary Task Descriptions	IIC8i
11 Schedule of Direct Labor· Codes 100-300	IIC8e (3)
11 Schedule of Direct Labor: Codes 400-500	IIC8e (3)
11 Schedule of Direct Labor: Code 600	IIC8e (3)
PART II TECHNICAL	
1 ERTS System	IIIC1-3a-c
2 ERTS System Specifications	IIIC3d
3 ERTS System Development and Activation	IIIC3e
4 Reliability Program Plan	IIIC3e (2)
5 Quality Program Plan	IIIC3e (3)
6 Test Monitoring and Control Plan	IIIC3e
7 Configuration Management Plan	IIIC3e (4)
8 Soldering Program Plan	IIIC3e
9 Failure Reporting Plan	IIIC3e
10 Maintainability and Safety Plans	IIIC3e
11 System Interfaces and Problem Areas	IIIC3f-g
12 Observatory System	IIIC4a (1) - (6)
13 Manufacturing	IIIC4a (7), IIIC6b (2), IIIC6c (2)
14 Observatory Specifications	IIIC4a (8)
15 Observatory Subsystems: Structure Thermal, Attitude Control, Orbit Adjustment	IIIC4b
16 Observatory Subsystems Communications, Data Handling, Antennas, Power, Electrical Integration	IIIC4b

PART II TECHNICAL	CORRESPONDING SECTION PROPOSAL INSTRUCTIONS
17 Observatory Integration and Test, Launch and Initial Orbital Operations, and Ground Support Equipment	IIIC4c-f
18 Data Collection System	IIIC5
19 GDHS Description, Plans, and Specifications	IIIC6a (1), (3)
20 GDHS Equipment Specifications	IIIC6a (2)
21 GDHS Software Specifications	IIIC6a (2)
22 GDHS Facilities	IIIC6a (4)
22A GDHS Facilities Design Criteria	IIIC6a (4)
23 Operations Control Center	IIIC6b (1)
24 Operations Control Center· Subsystems	IIIC6b (2)
25 Operations Control Center: Installation, Integration, and Test	IIIC6b (3)
26 Operations Control Center: Operations Support	IIIC6b (4) - (5)
27 NASA Data Processing Facility	IIIC6c (1)
28 NASA Data Processing Facility Image and Photographic Processing	IIIC6c (2)
29 NASA Data Processing Facility· Subsystems Other Than Image and Photographic Processing	IIIC6c (2)
30 NASA Data Processing Facility: Installation and Operations Support	IIIC6c (3) - (5)
31 Options	---
PART III BUSINESS AND COST/PRICE	
1 General Information and Exhibits A Through I	IVA-G
1A Award Fee Proposal	IVD2h
2 Summary Work Breakdown Structure	IVA
3 Schedule 1· Cost Analysis· Codes 100-300	IVC2a
3 Schedule 1: Cost Analysis: Codes 400-500	IVC2a
3 Schedule 1. Cost Analysis: Code 600	IVC2a
4 Schedule 2· Direct Hours. Codes 100-300	IVC2b
4 Schedule 2: Direct Hours: Codes 400-500	IVC2b
4 Schedule 2: Direct Hours: Code 600	IVC2b
5 Schedule 3: Materials: Codes 100-500	IVC2c, IVD2c
5 Schedule 3 Materials. Code 600	IVC2c, IVD2c
6 Schedules 4 and 5. Travel and ODC: Codes 100-300	IVC2c, IVD2e-f
6 Schedules 4 and 5: Travel and ODC Codes 400-500	IVC2c, IVD2d-f
6 Schedules 4 and 5 Travel and ODC· Code 600	IVC2c, IVD2e-f
7 Options	---
8 Data Collection System· General Information and Exhibits A Through I	IVA-G
9 Data Collection System: Schedules 1-5	IVC2

ADPE CONFIGURATION

The systems, subsystems, and operations described in this volume are necessarily developed around a generic computer configuration established before the ADPE procurement evaluation could be completed. The discussions therefore reflect the presence of a typical medium-sized computer for the OCC and a typical large-sized computer for the NDPF. Although all the functions to be performed in every case remain unaltered, the final ADPE selection of an IBM 360/85 and 44 configured as described in Final Report Volume 14, Section 5, and Proposal Part II, Volume 19, Section 2. 5, does result in certain differences in implementation. For example, it is stated that the OCC computer accepts PCM telemetry and writes a machine readable tape which is then used by the NDPF computer for the preparation of the master digital tape and extraction of attitude and annotation data. The processing functions in handling PCM telemetry are unchanged but the selected ADPE complex eliminates the need for the intermediate tape handling (OCC to NDPF) by utilizing high speed disc storage accessible by both computers.

Similar differences appear between the ADPE assumptions underlying the discussions and the actual ADPE design finally selected. In no case is there a reduction in capability and in many cases performance improvement is attained.

PRECEDING PAGE BLANK NOT FILMED.

CONTENTS

CONTENTS (Continued)

CONTENTS

1. OPERATIONS CONCEPTS

This volume describes the TRW design of the ground data handling system (GDHS). As an expository document little attempt is made in this book to present those design analyses and tradeoff studies which were a necessary concommitant to the synthesis of the system. Such background studies appear in other portions of this final report, particularly in Volumes 2, 15, 16, and 17. Consequently, in the following pages, the reader is given an unencumbered view of the GDHS configuration. Appropriate cross-references are provided to other report volumes wherein the rationale for certain design decisions may be found.

The GDHS top level specification is included in Volume 2 of this report. Subsystem specifications for the GDHS personnel subsystem, the OCC, and the NDPF are included as an appendix to this volume. Detailed equipment and software specifications (software Milestone B) constitute Volumes 20 and 21 of the proposal, Part II.

1.1 OVERALL PHILOSOPHY

The elements and functions of the GDHS are shown graphically in Figure 1-1 and are described in detail in Sections 2 through 6 of this volume.

The key to GDHS operations is on-line interactive support by separate but compatible computers in the operations control center (OCC) and the NASA data processing facility (NDPF). A unified display system augments the heuristic and judgmental efficiency of the human operators by providing the necessary man-machine interface with the highly efficient digital processors. Allocation of functions to hardware, computer software, or human operations has been based upon detailed studies of operations and functional requirements, and description of which may be found in Volume 15. The computer-based system is organized such that vital activities may continue manually during those periods of time that the automatic data processing equipment (ADPE) may be out of service. Furthermore, the tasks carried out by the OCC computer can be assumed by the NDPF computer, thereby providing complete machine backup for the OCC.

Certain activities are implicit to the relative objectives of the OCC and the NDPF as defined by the governing NASA specification S-201-P-3. Other GDHS functions which could reasonably be contained equally well within the OCC or the NDPF have been assigned on the basis of required response or throughput time for the process, relative loading of the OCC and NDPF, and the compatibility with other activities.

1.2 OCC OPERATIONS CONCEPTS

As the focal point of all ground facilities during the mission, the OCC must manage the observatory and tie together all of the personnel and ground facilities necessary for effective utilization of the ERTS payload resources. Beginning with user requests for specific geographic coverage, a series of plans is developed to coordinate the activities of personnel, ground facilities, observatory, and payload. The functions of the OCC may be classified as follows:

1) Operations Planning

   Mission Planning

   - Determine which user requests may be satisfied
   - Transform these requests into scheduled picture taking events.

   Operations Scheduling

   - Seek support of necessary ground facilities
   - Determine effect of latest weather predictions
   - Determine observatory and payload health requirements
   - Transform all requirements into a command schedule.

2) Operations Execution

   Pre-Contact Operations

   - Prepare all ground facilities for observatory control.

   Contact Operations

   - Marshall all ground facilities for observatory contact

FOLDOUT FRAME 1

FOLDOUT FRAME 2

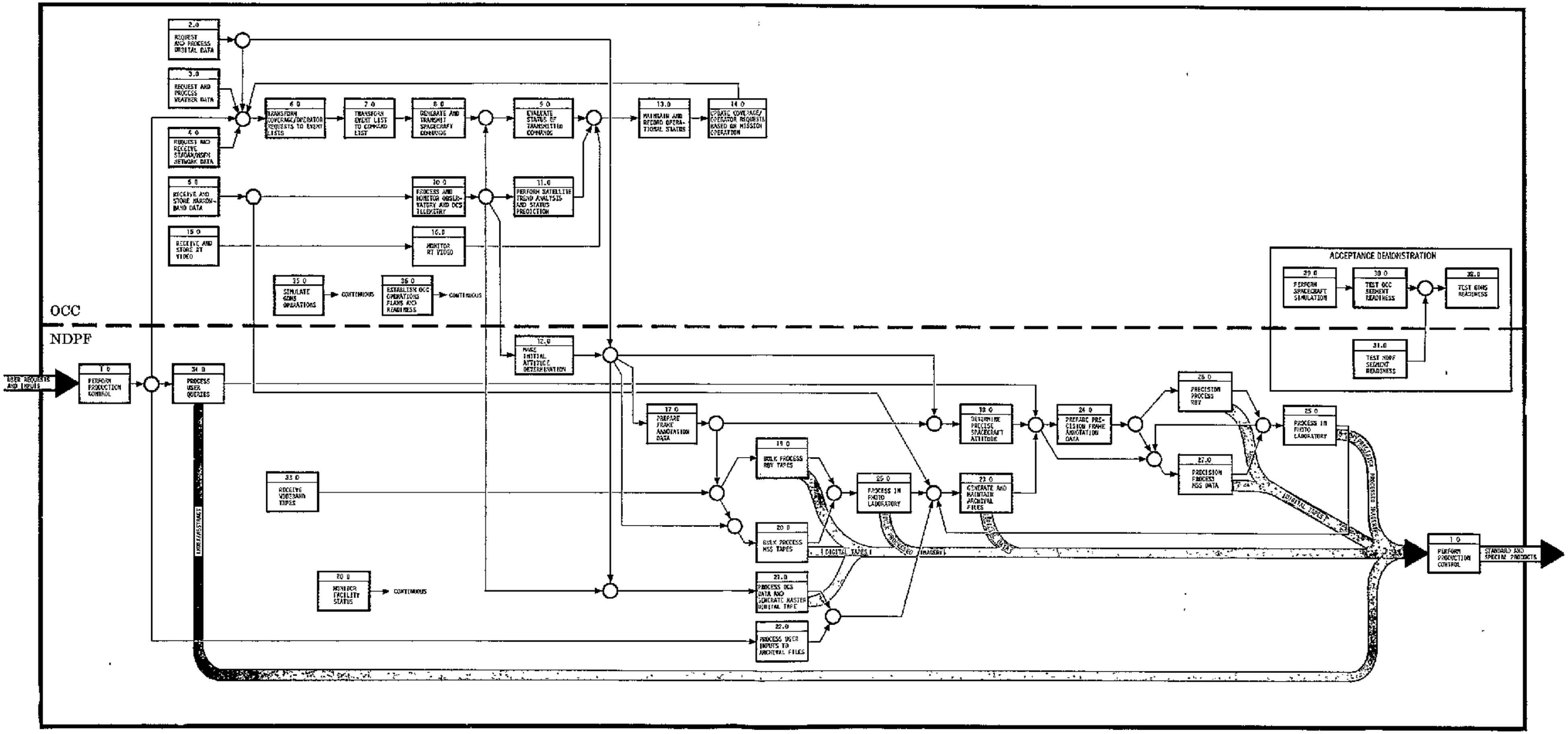


Figure 1-1

GROUND DATA HANDLING SYSTEM
top functional flow

PRECEDING PAGE BLANK NOT FILMED.

- Command and retrieve observatory data
- Monitor observatory and payload health.

Post-Contact Operations

- Analyze and report observatory and payload performance
- Maintain historical data file.

1.2.1 Mission Planning

The OCC plans the operation of the ERTS based upon user requirements, within the constraints of maintenance of spacecraft and payload health. The user liaison officer of the NDPF provides all user requests to the OCC properly prioritized and formatted for computer recognition. These are matched to observatory position, ground station coverage, and spacecraft and payload capabilities to produce a preliminary schedule of picture-taking events.

1.2.2 Operations Scheduling

The OCC schedules all ERTS activities and ground facilities to meet the mission planning requirements. Support of remote ground stations is coordinated through OPSCON and MSFNOC. Data links are obtained from NASCOM. Current observatory and payload status and health, along with ESSA weather predictions, are merged with the preliminary schedule of sensor events to produce a detailed schedule of spacecraft commands.

1.2.3 Pre-Contact Operations

The OCC requests of OPSCON, 1 week in advance, the reservation of STADAN and MSFN ground stations and NASCOM data links to those stations for satellite pass support. Confirmation is issued by OPSCON within 4 days. The NDPF is advised of the sensor events which are planned for that period so that workload may be scheduled and the user request file of the user liaison office may be updated.

1.2.4 Contact Operations

The OCC utilizes NASCOM wideband and high-speed data links for command transmission and telemetry data reception. The OCC will

transmit to each station its pass assignment one day prior to observatory contact. Each station will have the capability to receive real-time command messages from the OCC and radiate the commands to the observatory at OCC direction. Each station will have the capability to record all observatory originated data and relay the received PCM data to the OCC in real-time. The NTTF will have the added capability of relaying the payload and DCS data to the OCC and NDPF in real-time.

All housekeeping PCM data will be transmitted to the OCC in real-time for purposes of command verification, observatory analysis, and payload performance evaluation. DCS data will be transmitted to the OCC in near real-time by the Alaska and Corpus Christi stations in real-time by the NTTF. Real-time return beam vidicon (RBV) imagery and multi-spectral scanner (MSS) wave form displaying will be available in the OCC during NTTF passes.

1.2.5 Post-Contact Operations

The OCC converts all PCM and DCS data to computer readable, digitized magnetic tapes for further NDPF data reduction. Long-term, extensive analysis is performed on all data with a view toward impact on future operations planning. An historical file of digitized data tapes, strip charts, and computer printouts is maintained in the OCC. A monthly report will be issued, describing all significant spacecraft and payload events which transpired during that period.

1.3 NDPF OPERATIONS CONCEPTS

The eight major activities of the NDPF are:

- Screening of bulk RBV and MSS imagery for indexing, geographic tie-down, and basic data abstracting
- Accepting user abstracts, DCS, spacecraft, and supplementary data for incorporation into the data base
- Accepting, listing, and controlling user requests for special processing and coverage
- Maintaining, producing, and disseminating coverage indices, abstract catalogs, DCS, and spacecraft performance data

- Maintaining, producing, and disseminating RBV and MSS montage catalogs

- Maintaining all data files, film archives, digital data archives, historical montage data, and other hard-copy products, including both raw and processed data

- Reproducing and disseminating all bulk imagery (positive and negative transparencies and prints)

- Processing and distributing results of user requests for special imagery, special listings, plots, tapes, etc.

The NDPF serves as the user point of contact with the GDHS through the user liaison office. User liaison includes processing of user requests and providing the desired data either from the archives or by requesting new coverage from the OCC. Special requests may require special processing of either archival or new imagery.

All NDPF activities may be classified under two headings; information management and image processing.

1.3.1 Information Management

The information management function of the NDPF relates to the control of all data in the facility, including the following:

- Receipt and accounting of user requests

- Generation of requests for coverage, to be forwarded to the OCC

- Maintenance of files of processed imagery in the archives

- Maintenance of files of observatory performance and DCS digital data

- Retrieval of image or digital data on request

- Indexing of imagery for storage

- Incorporation of ERTS or user-generated abstracts in the imagery files

- Accounting for all outputs to users

- Production control and internal accounting.

These requirements are met by a flexible, computer-based information management system making maximum use of interactive display consoles. This system basically provides tables describing system input/output and data files so that one set of programs designed to operate interpretively with the tables performs all required processing. It provides special languages for the system user, permitting him to specify in English-like lanugage the file structures and the procedures and formats for maintenance, retrieval, and outputs.

All data inputs to the files can be described simply and are easily modified. Queries for specialized data are also readily specified. Editing features are available which guarantee that only correct data enters the file, providing a high degree of validity for geographical searches, the correlation of mission data with abstractions, and description files and information from the data collection system.

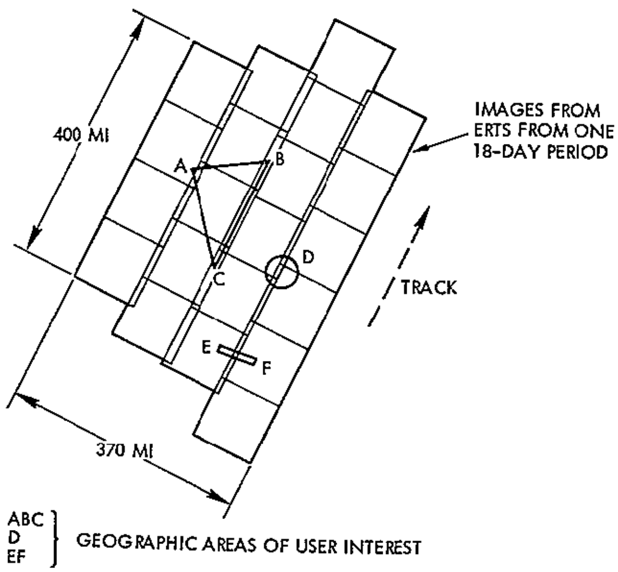
Data management techniques are used to build, maintain, and produce the index/abstract file and other associated formatted files. This involves the abstraction and indexing functions, as well as report and catalog production, retrieval techniques, and production control.

1.3.1.1 Imagery Indexing and Retrieval

Indexes in machine readable form are automatically generated from ERTS spacecraft attitude and orbital ephemeris data. The precision of this indexing is dependent on the error in source data such as sensor attitude and platform location at the time of exposure. The resultant file input will be the four corner coordinates of each frame set.

Vital information such as orbit time and date, spacecraft data, sensor data, sun angle, and spectral data will also be indexed, as well as percent of cloud coverage and quality of photography. The inclusion of this data in the index provides a flexible and responsive system which, in conjunction with abstract data, provides quick retrieval of coverage information.

With imagery geographically indexed, techniques are provided which allow users to retrieve coverage based on a geographic point, a



line, a radius about a point, and any polygon area. These geographic requirements can be modified by applicable time, quality, date, and content parameters.

Figure 1-2 illustrates the overlapping ERTS ground coverage and three possible query requests for index information which different users could request. Figure 1-3 illustrates the double data flow path associated with index file data flow.

Figure 1-2

POSSIBLE COVERAGE on three geographic areas of interest for one 18-day period

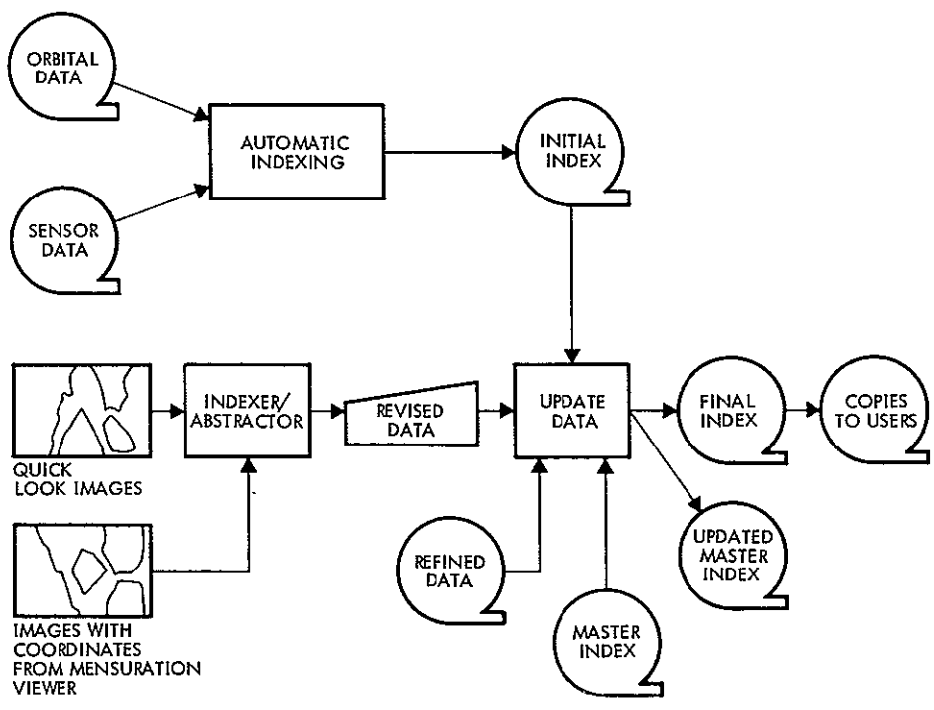


Figure 1-3

INDEX FILE data flow

The data base for the NDPF consists of a group of digital and hard-copy files as listed below:

Digital Files	Hard-Copy Files
Index abstract	Montage catalog
Data collection system	RBV black and white masters
Archive index	RBV color negatives
Observatory performance data	MSS black and white masters
Master digital data	MSS color negatives
Digitized image data	Precision image black and white negatives
Management production control	Ground reference data
User requests	Precision image color composite negatives
Request management	
Priorities User service indicator	Ground truth

1.3.1.2 Data Retrieval

The retrieval capability provides for extraction of specific data for user satisfaction. Most user's requests will specify requirements for information on single parameters which vary. These queries require a flexible retrieval language and program system which will retrieve the data, sort it on the basis of a stated order, correlate it with information from other files, and merge this data as required.

The retrieval language provides the following basic attributes:

- English-like statements containing a minimum number of terms
- Readily learned and written so that the user can structure his own query without resorting to a programmer for help
- States, in conjunction with his query, data organization and how he wants it output
- Specifies output media as cards, listings, plots, or magnetic tape.

Abstracts and Abstracting Procedures

Basic data elements of the file include both the index data and frame content descriptors. This is described in terms of four data types:

- Time and geographic location data
- Sensor-technical data
- Cross-reference data
- Results of user image interpretation.

Sensor technical data are fixed descriptors describing the conditions under which the imagery was generated; sun angle and scale (or altitude and focal length) and degree of processing.

Cross-reference data provides a user with references to reports in which either that particular frame is referenced or its content is applicable to the report results.

The data types and elements included in the index/abstract file are summarized as follows:

Data Type	Data Element
Time and geographic location	Source and time, four image corner coordinates
Sensor technical data	Sun angle, scale (altitude and focal length), processing applied, ground changes
Cross-reference data	Report reference, map reference
Results of image interpretation	Quality of imagery, cloud over percentage, fixed attributes (coded), keywords, unformatted textual comments

1.3.1.3 Annotation Data

The actual operation of abstracting involves reduction of the visual image to words and graphic description, so that an analyst can easily identify it for further detail and arrive at technical conclusions and recommendations. The GDHS unified display system consoles permit rapid and flexible information retrieval, analytical support, and communication of the results to the data files. Retrieval assistance

includes a "route-search" technique based on mission and index data that simulates the ground swath. This is used to assemble information automatically (map and document references, past coverage, etc.) for the analyst.

1.3.1.4 Production Control

Production control is responsible for the following functions:

- Insuring the availability of the required supplies (such as film, paper, cards) for a given operation
- Insuring the correct data tapes are input to the processor at the required time
- Processing user requests forwarded from the user liaison office
- Allocation of resources to assure efficient planned operation
- Reporting the results of prior production to management
- Projecting future scheduled activity for planning purposes
- Providing tradeoff studies of the above items to optimize cost and schedule commitments.

The data management system performs the majority of the file maintenance and retrieval operations in production control. Several data sets required to support the production control activity are:

- Data received and not processed
- Available resource descriptions and limitations (capacity per hour, etc.)
- Supplies inventory (films, paper, tapes, cards, etc.)
- Catalogs of available data
- Open user request/data reduction file
- Transaction history.

All of these data sets will be available on-line for any processing by the data management system, with tape copies retained for backup and off-line retrieval of special data. File design includes provisions for purging of inactive data to reduce the normal operational processing time

and to speed up the normal retrieval responses. Figure 1-4 illustrates the production control interfaces and Figure 1-5 depicts the scheduling of user requests.

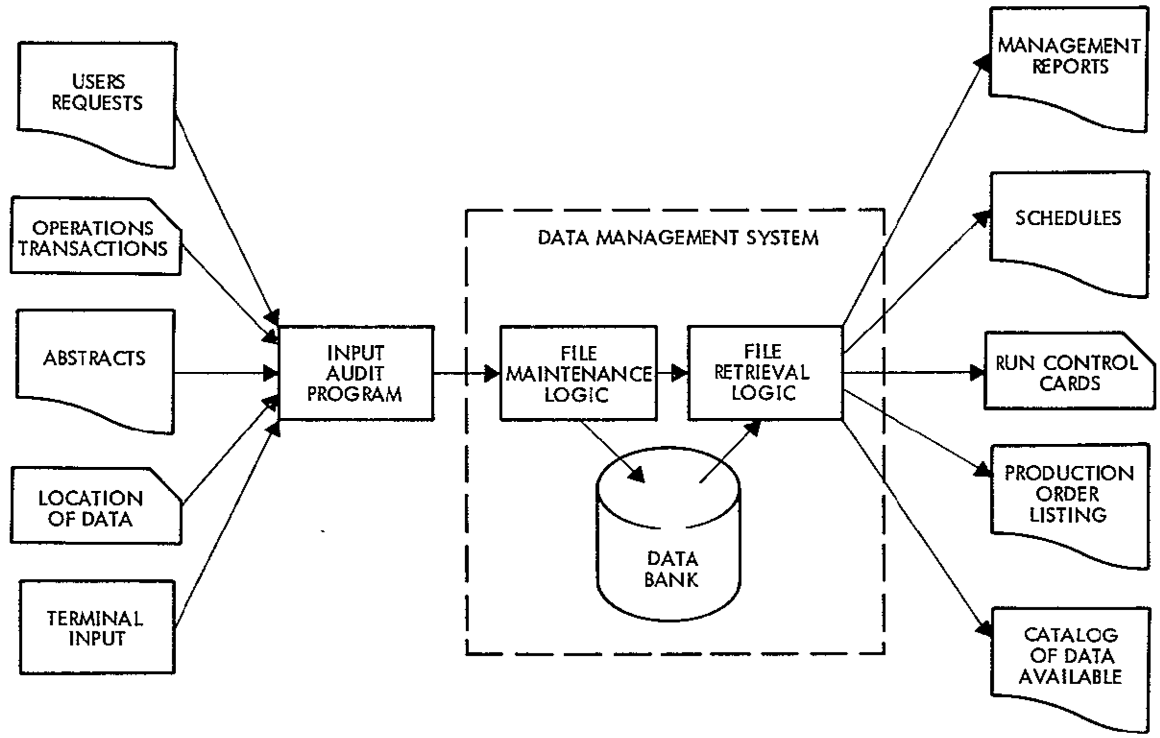


Figure 1-4
PRODUCTION CONTROL DOCUMENTS AND PROGRAM INTERFACE

1.3.2 Image Processing

The second basic operation within the NDPF is image processing which entails the conversion of the RBV and MSS into the forms, types, and quantities of photographic products required by ERTS users.

All received sensor data is batch-processed in the so-called bulk mode whereas a smaller quantity of images upon special user request receives further treatment in a precision mode. Both bulk and precision processing are examined in detail in Section 3.1 of this volume. The bulk mode produces photographic outputs of lower geometric accuracy than does the precision mode.

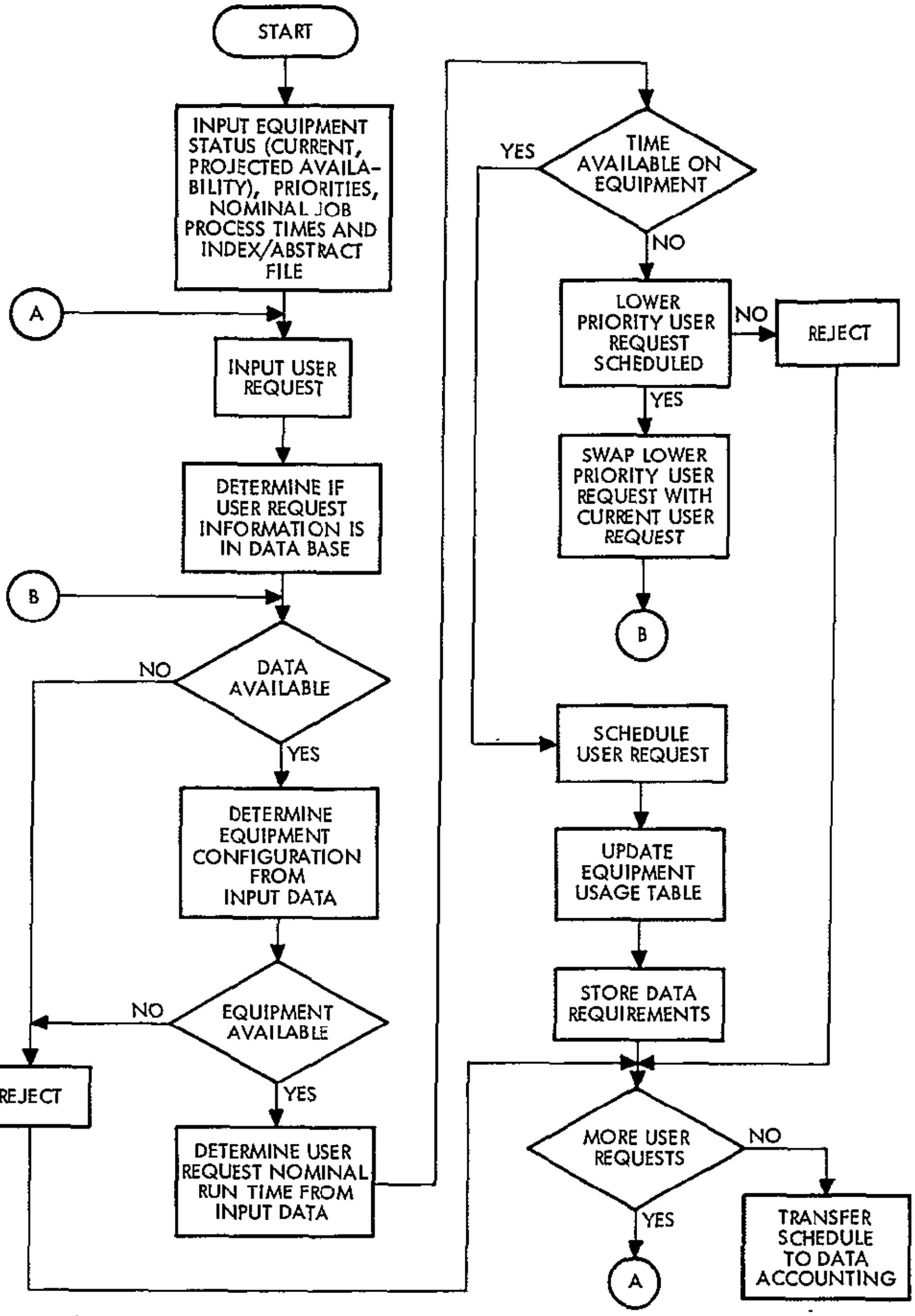


Figure 1-5
SCHEDULER flow diagram

A combination of digital and analog (optical) processing techniques has been selected after a series of intensive analyses to determine the optimal configuration based upon cost, operating speed, reliability, and accuracy (see Volume 17, Section 2.9).

The photo processing design is based upon conventional silver halide emulsions (see Volume 17, Section 5) and moderately high volume, batched operations, but with provision for priority and special request handling. Standard sensitometric techniques, developed during many years of industry application, assure uniform, precisely specified and controlled output products. They include periodic checking of equipment performance and solution chemistries with sensitometric test films, imposing a calibrated sensitometric grey-scale exposure on the head and tail of each roll of film, preliminary calibration of the sensitometry of each new batch of film stock, and examination of each intermediate product in the duplication chain.

A variety of photographic printers are provided for both bulk production and special request duplication to handle black and white and color products on either film or paper. All printers used are standard equipment of proven performance and reliability. Although most of the printing will be contact, there are provisions for enlargement and reduction printing for dissemination copies of output imagery on 70 mm film if so requested. Preparation of montages and special request material also involves optical printing.

Automatic photo processing machines are used to provide an adequate capacity for the volume of output products required and to permit careful control of different processing chemistries to assure the desired overall process gammas.

1.4 COMPUTING AND DISPLAY SERVICES

The computing and display services are treated as integral parts of the GDHS, although the OCC and NDPF have dedicated processors. The computers and other elements of the ADPE have been physically centralized in order to make efficient use of programmers, machine operators, maintenance and peripherals, and facilities. In a similar manner the unified display system provides machine output and input facilities for the OCC and NDPF.

1.4.1 Computer System

The GDHS computer system is based on the use of two distinct but compatible computers supporting the OCC and NDPF, respectively. Computer based functions are essentially the following:

OCC	NDPF
Observatory scheduling	Information management
Command generation	Production control
Message update	Bulk image processing
Telemetry processing	Precision image processing
Sensor coverage annotations	Displays
Displays	

The two computer systems are of the same model series from the same manufacturer, with lower level software compatibility. In this way, software normally assigned to the OCC computer can be run on the larger NDPF machine (see Section 5 and Volume 18). The two computer systems will also share a common direct access device so that there will be a common data and program base available in the event of a software-oriented shift in computer functions.

1.4.2 Unified Display System

Much of the normal operation of the GDHS makes use of interactive display consoles in the OCC and NDPF. A significant feature of the display system is that every console has access to either computer, hence the term "unified". This arrangement provides maximum flexibility for organizing and staffing GDHS operations and for handling various contingency situations.

All consoles in the unified display system are identical, which simplifies the initial procurement and permits the system to be expanded as needed at minimum cost. Additionally, any console terminals normally assigned to NDPF tasks can support contingency or peak load OCC operations.

The display technique selected as best suited to GDHS requirements is known as digital television (see Volume 15, Section 4). With this technique, computer output is converted to video signals that are used

to drive essentially standard television monitors. System flexibility is significantly increased, especially in that analog video imagery from videotapes or closed-circuit television cameras can be mixed with the digital input. The major advantages of digital television for the GDHS display system are:

- The display consoles are simpler, cheaper, and easier to maintain
- Additional consoles and/or monitors (slaves) can be added at a later time without changing the basic configuration
- Video signals from other sources can be combined with the digital input
- The system is stable and requires little adjustment
- Source-to-display distances are not critical
- Polarity can be reversed (white-on-black or black-on-white) at the user's option.

The display generator, including its input/output buffers and data adapters, interfaces with both the OCC and NDPF processors and provides 14 display channels to consoles and monitors. Any console in the system can access any part of the data base, and the system will automatically direct the request to the computer controlling that data.

Five consoles are planned for the OCC and five for the NDPF. Each console has complete input/output facilities including an alphanumeric keyboard for message inputs, a program function keyboard for fixed command inputs, and a track ball for cursor inputs. Console displays are 17-inch (diagonal) cathode ray tubes with an extremely stable image and a large character and format repertoire. The console displays are supplemented by four large (21-inch diagonal) ceiling-mounted monitors in the OCC (two in the planning area and two in the command area).

1.5 COMMUNICATIONS AND DATA ACQUISITION

The NASA communications and data acquisition facilities currently in use will meet all GDHS requirements, with certain special

modifications. The GDHS interface with these facilities will be NASCOM. Tracking and orbit determination will be handled by NASA outside of the GDHS framework, with computed observatory ephemerides provided periodically for use in mission planning and imagery annotation.

NASCOM communication circuits provide access to the Manned Space Flight and Space Tracking and Data Acquisition Networks. Teletype, voice, and digital and analog data links are provided, with a range of data rate capacities.

Table 1-1. Dedicated ERTS Ground Stations

Station	Affiliation	Downlink		Downlink		Downlink S-Band Sensor Data
		S-Band	UHF	S-Band	UHF	
Alaska	STADAN		X	P	X	P
Texas	MSFN	X		X		P
NTTF	GSFC-MSFN			X	X	P
Rosman	STADAN		X		X	

NOTE: X = Present capability
P = Planned capability for ERTS

Three ground stations have been designated as dedicated ERTS stations: Gilmore Creek, Alaska; Corpus Christi, Texas; and Rosman, North Carolina. The NTTF at GSFC is available as a downlink station. Table 1-1 lists the characteristics of these stations. Station communication functions are as follows:

- Texas will receive all downlink transmissions and will transmit command over an S-band (2106.4 MHz) uplink. Telemetry from the observatory will be routed to the OCC in real-time on the 2.4 or 4.8 kbit/sec links; RBV and MSS wideband data will be recorded on tape and mailed to the GDHS. DCS data can be transmitted only after conversion to digital form at the ground station, unless a wideband (20 kHz or greater) circuit is added. In that case the DCS data could be transmitted by means of slow playback of the station recorder.
- Alaska will be modified to accept all ERTS downlink transmissions and will transmit command over a VHF (154.2 MHz) link.

Telemetry data will be transmitted to the OCC in real-time at data rates of 2.4 or 4.8 kbits/sec or over the X-144 wideband link at rates as high as 32 kbits/sec (NRZ). DCS data will be recorded and retransmitted to the GDHS by slow playback over an existing 23 kHz channel in the X-144 link. It would also be possible to convert the DCS data to digital form at the station and transmit it over a digital link.

- NTTF is located at GSFC and is a receive-only facility. The associated uplink commanding will be done through Rosman. Transmissions received at the NTTF will be routed directly to the GDHS in real-time; wideband video links to the GDHS will be required for this purpose (quick-look only). Image processing will be performed on tapes recorded at the NTTF and physically delivered to the NDPF.

- Rosman will be used only for uplink commanding, command messages will be relayed by the NTTF to Rosman for transmission to the observatory. These messages will be sent over voice/data circuits (2.4/4.8 kbits/sec) or over a 15 kHz wideband link. The Rosman station will probably also receive the 1 kbit/sec downlink telemetry signal, but will use it only for on-site command verification by inspection of the telemetry. In a back up mode Rosman could route the 1 kbit/sec telemetry to the NTTF for relay to the GDHS.

During launch and early orbit support, several MSFN and STADAN stations should be made available to provide the ERTS OCC with real-time and near-real-time telemetry data during critical portions of the ERTS orbital flight. Figure 1-6 shows the ground track of the ERTS during the first two orbits. From this illustration it is seen that little of the first orbit segment, from Vandenberg to South Africa, crosses within the acquisition range of a MSFN or STADAN station. During this segment of the first orbit the WTR will provide tracking data (C-band radar) and low bit rate VHF telemetry via high-speed data lines to the GSFC. Teletype and voice/data circuits also connect GSFC with the WTR (Point Arguello, Calif.). Guaymas or Goldstone could also be used to track ERTS for some portions of the ascent trajectory from Vandenberg to approximately 10°N of the equator. These stations could acquire the spacecraft at S-band, perform the S-band pseudo-random noise ranging sequence and receive low bit rate telemetry. The ability of Guaymas to receive telemetry may be somewhat marginal, however, since Guaymas has an uncooled paramp that will degrade circuit margins roughly 3 db.

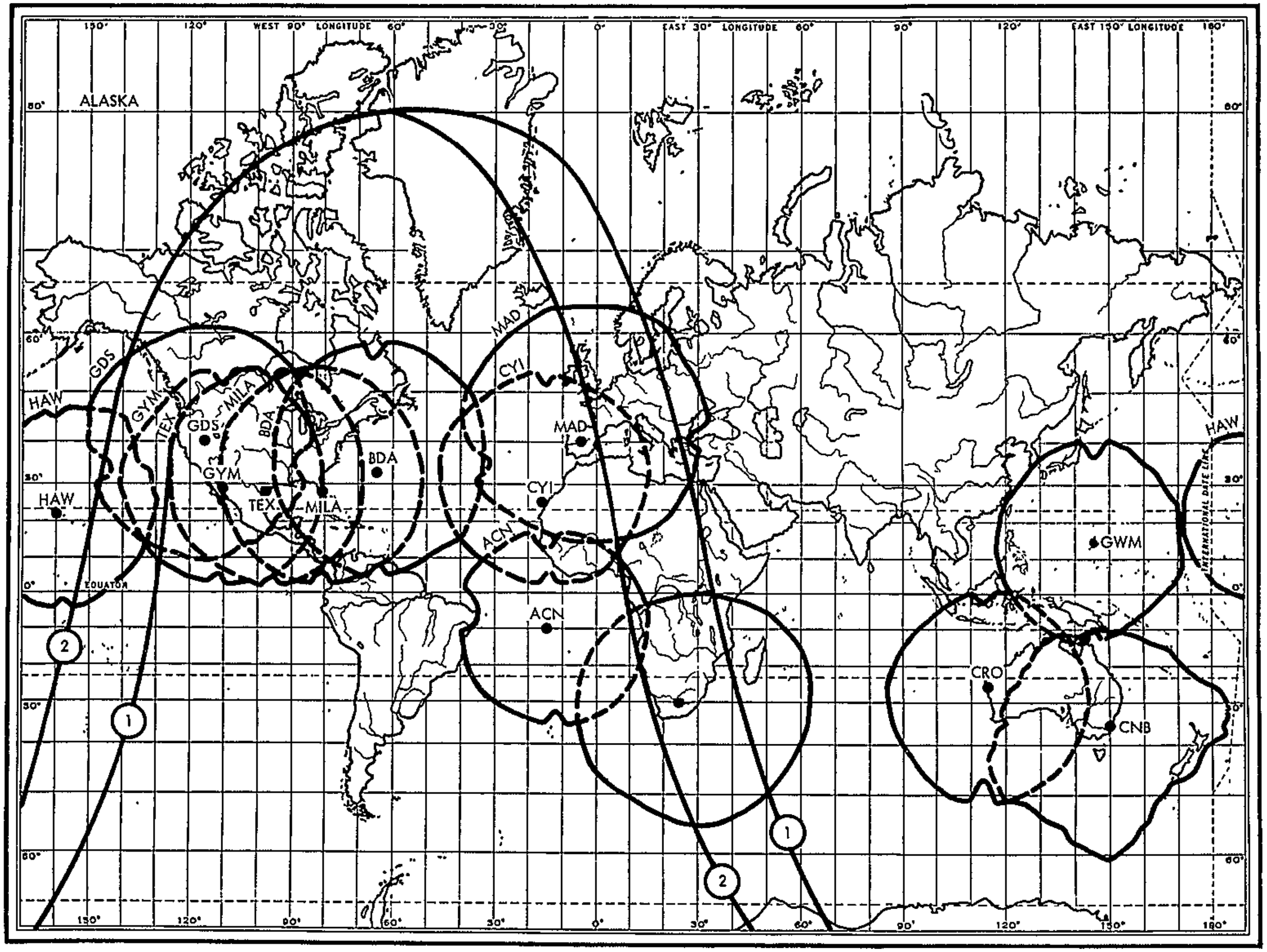


Figure 1-6

TOTAL MSFN UNIFIED S-BAND COVERAGE for ERTS

1.6 FACILITIES

The facility identified at GSFC for GDHS installation is the second floor of Building 23. It was originally designed and built to accommodate electronic system development laboratories and computer data processing equipment.

The TRW GDHS facility plan for Building 23 consists of modules arranged to form the following functional work areas:

- Operations control center (described in Section 2.5 of this volume)
- NASA data processing facility including the telemetry image data processing area and the data services laboratory (described in Section 3.6 of this volume)
- NASA browse room, conveniently located for NASA user service.

TRW planned the Building 23 GDHS facility to meet the following general requirements that will benefit the program, equipment operations, and personnel:

- Maximum use of space
- Allowance for system growth
- Use of existing facilities (corridors, partitions, lights, etc.), without modifications wherever possible
- Economical modification of existing facilities within time schedule
- Compatibility between electronic and chemical processing equipment
- Efficiency of operation
- Safety control, contamination and environmental control, and control of disturbances such as noise and traffic
- Phase occupancy
- Convenience to NASA users.

Studies and tradeoffs leading to TRW's final facilities plan are described in Volume 15, Section 3, Facilities Design.

The major portion of the floor area of Building 23 is equipped with a computer floor system that will meet GDHS equipment requirements.

All engineering and program office personnel will use the existing peripherally located offices and will not require partitioning changes in the space assigned. All existing restrooms and other service areas will be retained as is; they are easily accessible to all areas of the GDHS.

A special emergency battery powered light system is provided throughout the facility should there be a loss of the main building electric system.

All major system displays or control stations that support system operations and examples of special processing operations will be located in glass partitioned rooms visible from main corridors. The visitor control plan retains existing corridors that are accessible to multiple-purpose briefing and planning rooms. If more space is needed, it will be available with the operating areas. A phase occupancy plan will totally separate:

- Electronic equipment areas that require minor modifications and will be ready to receive equipment for installation and checkout first,
- Data storage and support areas (finished second)
- Photo processing areas that will be finished last because of major modification requirements.

Environmental control and containment of chemical fumes will be provided by separate rooms positive pressure zones. Each major processing element of the system will be located in separate partitioned areas.

TRW will eliminate or redirect corridors as necessary to maximize use of the total facility. Materials from the deleted partitions will be reused.

In planning new configurations TRW aligned partitions so that major changes to the modular location of the lighting fixture system would be minimized. The size and the direction of swing of existing doors was determined indicating that all doors will be reusable.

Existing utilities such as electric power panels and building grounding systems can be used with only minor changes. The removal of old power cabling and other wiring previously installed will be required to permit installation of new harnesses to the equipment modules. This approach will eliminate confusion caused by excess cabling and will eliminate electric short-circuit damage to equipment and personnel safety. Additional technical grounding systems will be required to minimize operating and installation problems. The existing convenience outlet power strips will be relocated and reused in the various areas requiring supplemental nontechnical power sources, reducing construction costs.

The existing computer floor structure will be used but will require replacement of some panel sections previously modified for special equipment requirements.

The existing building air conditioning supply system is capable of being modified without major expense, and will be augmented by a dedicated system for use by the electronics area to help guard against possible corrosion damage from the chemical fumes in the telemetry and data image processing areas. Minor ducting changes and rebalancing of the various zones to allow for the new equipment layouts will be required.

TRW's partitioning master plan will not require major realignment or modification of the lighting system. The control center operations room and the browse room will require that separate switching for the fluorescent fixtures and the addition of supplemental incandescent type flood lights with intensity controls located in the room.

CONTENTS

2. Operations Control Center

2. OPERATIONS CONTROL CENTER

The operations control center is the focus for all the operating functions of the observatory. Observatory health, configuration, and command response is monitored by computer analysis of real-time PCM data received at the OCC during ground station reception. The computer functions as a sentinel to alert OCC operations personnel, through a defined set of priorities, of potential failures and critical conditions detected in the telemetry stream. Telemetry parameters are available to operations personnel through the interactive unified display system. Direct readout of specified data parameters at the OCC and remote stations, independent of the computer, is available as a backup method of data presentation.

Satellite commands are selected on a pass-to-pass basis at the OCC and transmitted to the tracking stations for relay to the satellite. Commands are generated by a set of programs that act on a previously developed list of events. An event is an observatory operation which requires a number of commands to implement. Primary observatory command is exercised through computer via specific STADAN and MSFN stations. Alternate command transmission is provided independent of the computer, utilizing command encoders located at each station.

Data processing in the OCC supports the operations personnel in scheduling spacecraft and payload activities, generating commands for the spacecraft, determining the health of the observatory from telemetry, and predicting sensor coverage. Spacecraft scheduling is performed by software under control of manual inputs. Command message generation is automatic, with manual control and override available.

The mission planning within the OCC is based upon coverage requests and priorities received from the NDPF. The planning function takes into account constraints imposed by current observatory operating parameters and determines those requests which will be most expeditiously obtained from a specific pass. Other constraints on OCC planning are

those imposed by weather conditions over the area to be imaged. These data are obtained from the Space Operations Support Division in Suitland, Maryland.

2.1 FUNCTIONAL AREAS

The operations control center is divided into three primary functional areas: 1) the control area, 2) the planning area, and 3) the equipment area. These divisions are illustrated in the OCC floor plan, presented in Section 2.6, Facility Plan (Figure 2-37).

2.1.1 Control Area

The focus of OCC real-time operations is contained within the control area. It is from here that all operational decisions are made and implemented. Ground commands transmitted from this position and all observatory status and health data is monitored.

This area contains three control and monitoring consoles. The center console is manned by the operations planner controller who has responsibility for overall operation of the observatory. This requires coordination of all internal OCC activities, reviewing all detailed pass assignments and command lists, monitoring observatory command status, and transmission of commands to the spacecraft. Further, this position is responsible for coordinating and communicating with external groups such as OPSCON, MSFNOC, NETCOM, ESSA, and the ground station.

The data analyst is positioned at a side console and is primarily responsible for monitoring and evaluating observatory status and health. Trend analysis and subsystem engineering activities are performed utilizing cathode-ray tube displays and strip chart recorders. Corrective action to improve spacecraft and payload performance is recommended to the operations planner controller as required.

The other side console is manned by the command generation technician. This position is responsible for monitoring the command lists and providing general command support to the operations planner controller. The computer-generated command lists are reviewed for accuracy with corrections and additions being made as required.

In addition to the control consoles, two large overhead cathode-ray tubes are provided for group viewing. These displays present general status information and forced alarm messages indicating any anomalous conditions.

2.1.2 Planning Area

The OCC mission and planning area is located adjacent to the control area and is used as a work area for functional support to the control personnel. This area provides facilities for sensor scheduling and review of PCM spacecraft data. These facilities include two control consoles, two overhead cathode-ray tubes for group viewing, and reference tables for engineering analysis and pre-pass/post-pass conferences.

The consoles provide interface with all OCC software in support of mission planning and event scheduling. These consoles are also used as backup to the control area consoles in the event of a console malfunction or during periods of peak activity.

2.1.3 Equipment Area

The equipment area contains all components for data handling and processing with intent of minimizing noise disturbances to the adjoining control and planning areas.

This area contains the PCM and DCS data handling equipment, PCM tape recorders, MSS scope and viewing camera, communications terminal, and the line printer.

2.2 OPERATING STAFF

Functional flow diagrams and requirements allocation sheets (Volume 15) provided the basis for task identification and staffing within the OCC. Analysis of the function/tasks, related equipment, and operation procedures required to meet mission objectives led to the identification and categorization of tasks in generic terms. The tasks were reviewed and assigned to manned positions based on task flow information, task criticality, amount of time required to perform each task, task frequency and schedule, task commonality, and the equipment associated

with the task performance. Task and equipment requirements were then reviewed to determine the number of personnel and operational shifts required during routine orbital operations to accomplish the tasks at each manned position, and, in turn the organizational structure of each operating area.

Results of the analyses indicate that during routine orbital operations several positions require manning for 8 hours per day, 5 days per week, and others for a 24 hours per day, 7 days per week. In computing the total staffing requirements, a manning factor of 1.0 was used for single shift operations and 5.0 for those positions requiring manning around the clock. Table 2-1 lists the estimated number and type of personnel required.

The duties for the positions listed in Table 2-1 are as follows:

1) OCC Manager

- Responsible for the operation of the OCC and the performance of the operations and support personnel
- Plans, supervises, and coordinates operations and maintenance activities within the OCC
- Presents command and control operations to ERTS project management
- Interprets NASA policies and activities for OCC personnel
- Determines optimum personnel practices, manpower levels, budget requirements, and training programs
- Establishes schedules and manning necessary to meet operating requirements and determines alternate sources of action as schedules change
- Reviews and approves the OCC daily activities schedule.

2) Staff Analyst

- Reviews accomplishment of daily schedules and reports deviations
- Prepares daily OCC activity schedules

- Prepares inputs in the form of prioritized maintenance tasks for inclusion in the OCC daily schedule
- Prepares observatory and payload operational reports
- Coordinates activities of subsystem analysts (position 7).

Table 2-1. Planning Estimates

Position	Total No. of Personnel Required	Personnel Type
8 hr/day, 5 days/week		
1) OCC Manager	1	Engineer
Secretary	1	Secretary
2) Staff Analyst	1	Engineer
Secretary	1	Secretary
3) Staff Administrator	1	Admin.
Secretary	1	Secretary
4) Mission Planner	1	Engineer
5) Training Supervisor	1	Engineer
6) Subsystem Analyst	1	Engineer
Imagery Analyst	1	Engineer
ACS/Power Analyst	1	Engineer
Communications Analyst	1	Engineer
7) Computer Programmer Section Head	1	Engineer
Programmers (2)	2	Technicians (2)
24 hr/day, 7 days/week		
8) Data Analyst	5	Engineer
9) Operations Planner Controller	5	Engineer
10) PCM Technician	5	Technician
11) Command Generation Technician	5	Technician
12) Data Technician	5	Technician
Total	40	

3) <u>Staff Administrator</u>

- Insures that administrative requirements of ERTS staff and operational personnel are satisfied
- Prepares reports in conjunction with other staff members.

4) <u>Mission Planner</u>

- Provides weather interpretations and predictions to operating personnel
- Provides on-the-job training to operational planner-controller for around the clock weather predictions
- Generates operating procedures for STADAN stations to support ERTS passes
- Establishes schedules of activities required to generate and distribute command lists for each observatory pass
- Establishes schedules and manning necessary to meet operating requirements, and determines alternate courses of action as schedules change
- Reviews the OCC daily schedule to determine position-related assignments
- Provides master schedule and long-term planning; coordinates with all shifts to ensure continuity of operations
- Prepares reports.

5) <u>Operations Training Supervisor</u>

- Provides simulated training exercises to newly assigned OCC personnel utilizing script material. Utilizes hardware and software in training exercises as they become available
- Responsible for the training of all personnel
- Coordinates with operations controller and planners and systems analysts in obtaining training material and training assistance
- Provides refresher training to experienced personnel and cross-training of equipment procedures.

6) <u>Subsystem Analysts</u>

- Reviews pass schedules for payload activity
- Receives payload data and selects one of three video signals for display
- Evaluates sensor performance; examines video images for quality and cloud cover; confirms basic data quality
- Evaluates mission performance; compares sensor coverage against affected coverage
- Specifies corrective measures; determines actions required to improve image quality
- Adds annotation comments to video data
- Generates quick-look report including unfulfilled sensor coverage report.

7) <u>Computer Programmer</u>

- Maintains all OCC applications programs
- Coordinates work with NDPF programming head
- Writes programs and routines, and prepares flow charts and diagrams as required.
- Checks equipment and performs readiness tests to ensure OCC data processing and display equipment are in an operational mode
- Assists training supervisor during simulated training sessions. Operates tape decks and ensures equipment is operating properly.

8) <u>Data Analyst</u>

- Monitors and evaluate current observatory and sensor health
- Performs trend analysis on required observatory and payload data
- Performs subsystem engineering utilizing displays and strip charts
- Recommends corrective action to improve observatory and payload performance

- Maintains history of utilization of critical observatory and payload items
- Performs long-term trend analysis.

9) Operations Planner Controller

- Coordinates OCC activities
- Coordinates station support schedule with OPSCON
- Coordinates the establishment of voice and data links required for ERTS operations
- Communicates with STADAN stations during pre- and post-pass activities
- Reviews assignment of observatory acquisition opportunities versus users requests
- Reviews command list, event list, orbit corrections, recorder budget, power budget, and weather data
- Reviews support schedule
- Monitors observatory command status
- Monitors stored command programmer status and contents
- Checks observatory command sequence against user requests and resolves conflicts
- Transmits commands to spacecraft as required
- Reviews observatory command history
- Checks observatory telemetry for parameter values and equipment status changes associated with verification of command execution
- Reviews and modifies command lists for each station pass
- Alters command list based upon weather predictions
- Performs long-term trend analysis.
- Requests orbital data, weather data, and STADAN/MSFN support

- Forwards messages and instructions necessary to support ERTS passes to STADAN/MSFN stations
- Verifies receipt of command messages by STADAN/MSFN.

10) <u>PCM Technician (Maintenance and Operations)</u>

- Maintains and operates PCM tape recorders, PCM data handling equipment, strip chart recorders, and scopes
- Implements requested strip chart and tape recorder channel assignments and prepares an updated list of channel allocations
- Configures and monitors telemetry data handling equipment prior to pass related activities
- Labels, packages, and stores tape and strip chart recorder outputs.

11) <u>Command Generation Technician</u>

- Compares systems analyst requests against payload and observatory status to maintain observatory continuity
- Inputs user requests from NDPF to computer
- Reviews computer generated event list for accuracy, conflicts, and additions and deletions
- Reviews stored command programmer preliminary command sequence, command history
- Communicates spacecraft and sensor events to NDPF
- Maintains OCC historical file.

12) <u>Data Technician</u>

- Reviews ephemeris and orbit data versus station pass time
- Prepares and distributes daily OCC time sequence activity to support ERTS operations
- Maintains surveillance of OCC consumables
- Prepares ground support schedules
- Generates station pass checklist.

2.3 OBSERVATORY MANAGEMENT

Management of the ERTS observatory consists of the tasks necessary to insure effective utilization of the satellite/payload system. These tasks are categorized as launch and initialization, contact operations, command generation, command transmission and verification, subsystem monitoring and evaluation, and payload utilization.

2.3.1 Launch and Initialization

The role of the OCC during the launch phase is limited. From an orbital question standpoint, the only requirements on the observatory prior to launch are:

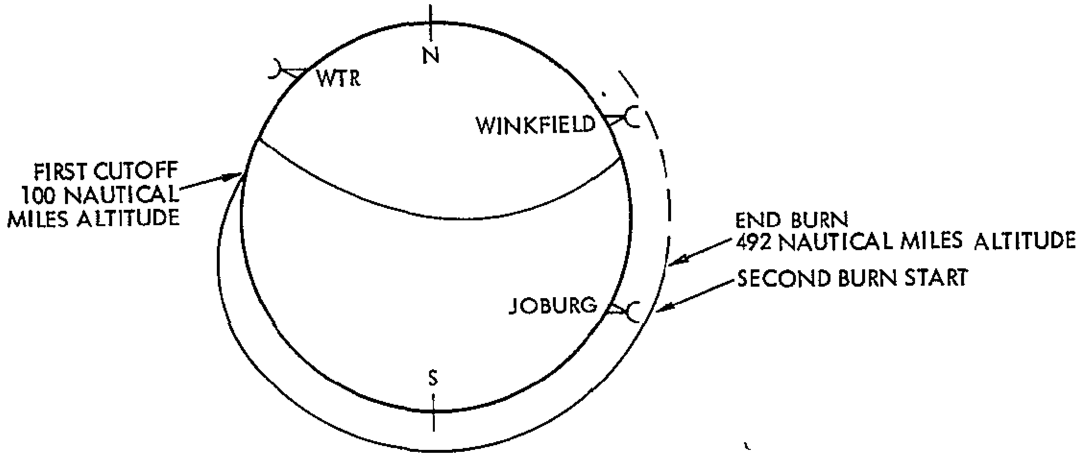
- Proper launch configuration of all commandable components
- Full charge of both batteries
- Spacecraft clock to GMT correlation
- Stored command programmer is unloaded and off
- VHF and unified S-band transmitters are on and operating.

Past experience indicates that the project operations director at the OCC should be in voice contact with the launch area at the Western Test Range to assume that all of the above functions are carried out on schedule. It may be advisable to transmit 1 kilobit data over leased land lines so that all telemetry may be verified at the OCC. It should be emphasized that the OCC does not establish contact with the observatory until orbital injection, approximately 55 minutes after liftoff, when the Delta second stage inserts the observatory into circular orbit.

The injection occurs after the sequence of events shown in Figure 2-1. Delta first burn terminates at about 100 nautical miles altitude and the spacecraft coasts halfway around the earth. Delta second burn is brief but circularizes the orbit to within a few miles. Deployment is observed at both the Johannesburg and Madagascar stations.

2.3.1.1 Sun Acquisition Procedures

Both African stations will monitor telemetry data but will send only one command, deploy backup. Attitude control will remain in



	SEQUENCE OF EVENTS	STATION
0	LIFTOFF	WTR
40	SOLID SHUTOFF	WTR
220	THOR SHUTOFF, MECO	WTR
235	THOR DELTA SEPARATION	WTR
289-524	DELTA FIRST FIRING	NONE
330-3304	DELTA SECOND FIRING	MADGAR
3364	ERTS-DELTA SEPARATION	MADGAR

Figure 2-1
ERTS LIFTOFF AND ORBITAL INJECTION

mode I, with spacecraft tumbling slowly until Alaska sighting. At Alaska, the attitude control system will be commanded into mode IIb and sun acquisition monitored. Telemetry data from Madagascar, Alaska, and several other STADAN stations will be available in real-time at the control center for monitoring the events. Mode IIb calls for acquisition of the sun, using sensors at the end of the array. Reaction wheels and control gas jets come into play to torque the spacecraft. The array is fixed with its solar cell active surface facing toward the tape recorder (+Y) end of the spacecraft. At the same time that the control forces begin to bring the spacecraft around to point at the sun, a rate gyro is spun up and develops an error signal which can only be removed by a low rate of rotation of the spacecraft around its long (pitch) axis. The sun acquisition and pitch spinup maneuver takes only a few minutes and should be completed during the real-time viewing from Alaska. The spacecraft housekeeping tape recorder is dumped at Alaska toward the end of the 12-minute pass. This playback requires 3 minutes and will be received at the OCC at a 16 kilobit rate immediately following the conclusion of the Alaska pass.

The spacecraft continues to track the sun and is not viewed from a ground station until it is in eclipse over Johannesburg. Real-time data is relayed from Johannesburg to Greenbelt via the DCS low bit rate communication link which suffices since only a selected small portion of the data is needed. A similar arrangement gives the OCC data from Winkfield where it is viewed next during a 15-minute pass. As the spacecraft continues to rotate in pitch (at 0.5 deg/sec) it will drift off the sun pointing line. When exiting from eclipse, a small amount of gas will be used to reacquire the sun.

2.3.1.2 Earth Acquisition Procedures

If all is well to this point as revealed by examination of tape playback and real-time data, entry into earth acquisition mode IIc is commanded at Alaska on the second revolution. Earth stabilization begins when three of four horizon tracker heads lock on the earth. Again, the control forces act to orient the spacecraft until the error signal from the tracker is nulled (a condition where the +Z body axis is closely aligned to earth center). Mode III describes this condition and in this mode the solar array is permitted to rotate until the array normal vector points toward the sun.

The spacecraft is next viewed at Canberra, Australia for about 15 minutes. Again real-time data is relayed to GSFC but this must be interrupted to dump the housekeeping tape recorder for 4 minutes. Again the tape playback will be sent to the OCC via the DCS data link.

2.3.1.3 Yaw Acquisition Procedures

Yaw acquisition will be delayed until Santiago, Quito, Rosman, and Alaska provide 45 minutes of continuous viewing. This occurs on revolution 4 which becomes revolution 5 at the equator. This sequence occurs in eclipse, which in mode III sees the spacecraft pointing to earth, but drifting slowly in yaw as result of wheel rundown. Mode IV will be commanded when the observatory's attitude is nearest to alignment with the yaw plane. At entry into eclipse, the spacecraft would have been about 60 degrees off the desired yaw attitude (-X axis leading along flight path), and it is likely that yaw wheel rundown in eclipse will rotate

the spacecraft towards the desired attitude. Mode IV is entered with a slow turn and in this case (60 degree initial error) about 50 minutes will be required to reduce yaw error to a few degrees.

2.3.1.4 Initial Payload Tests

The payload turn-on phase will be delayed until revolution 12 when the spacecraft is in sunlight over the Rosman station. Revolution 12 provides a sweep over northeastern Canada which may be used for a quick check of RBV imagery. The data collection system is also commanded on at this time to remain on henceforth. Revolution 13 provides a mid-continent sweep of North America and will be used to first activate the MSS. NTTF and Texas stations can simultaneously receive most of the payload data during this pass. On the subsequent pass, revolution number 14, the two video tape recorders are first used together with the two sensor data sources. Only a brief trial is possible since record and playback must be completed within the 11-minute Alaska pass. Subsequent recording operations will be commanded entirely by stored programmer with stored data played back during eclipse. Checkout of the stored command programmer will begin with operations in view of the ground station by altering the status of unimportant functions on a short time scale. With confidence in the programmer established, the orbit adjustment process may begin.

2.3.1.5 Orbit Adjust Procedures

To provide a complete mapping of the earth surface in 18 days, a precisely controlled orbit is required. The orbit parameters needed are:

Period:	103.3 minutes
Inclination:	99.098
Eccentricity:	0.001
Semi-major axis:	3934 n mi (altitude 490 n mi)

The orbit desired is as circular as feasible for constant picture dimensions. Period control is a first-order requirement for overlap of adjacent tracks. Inclination and altitude together determine sun synchronism, i.e., orbit rotation of about 1 degree per day.

The booster is not sufficiently accurate to achieve the desired orbit. A full description of its errors and the required correction is given in Volume 2 of the Phase B/C Study Report. The orbit adjust system is diagrammed in Figure 2-2.

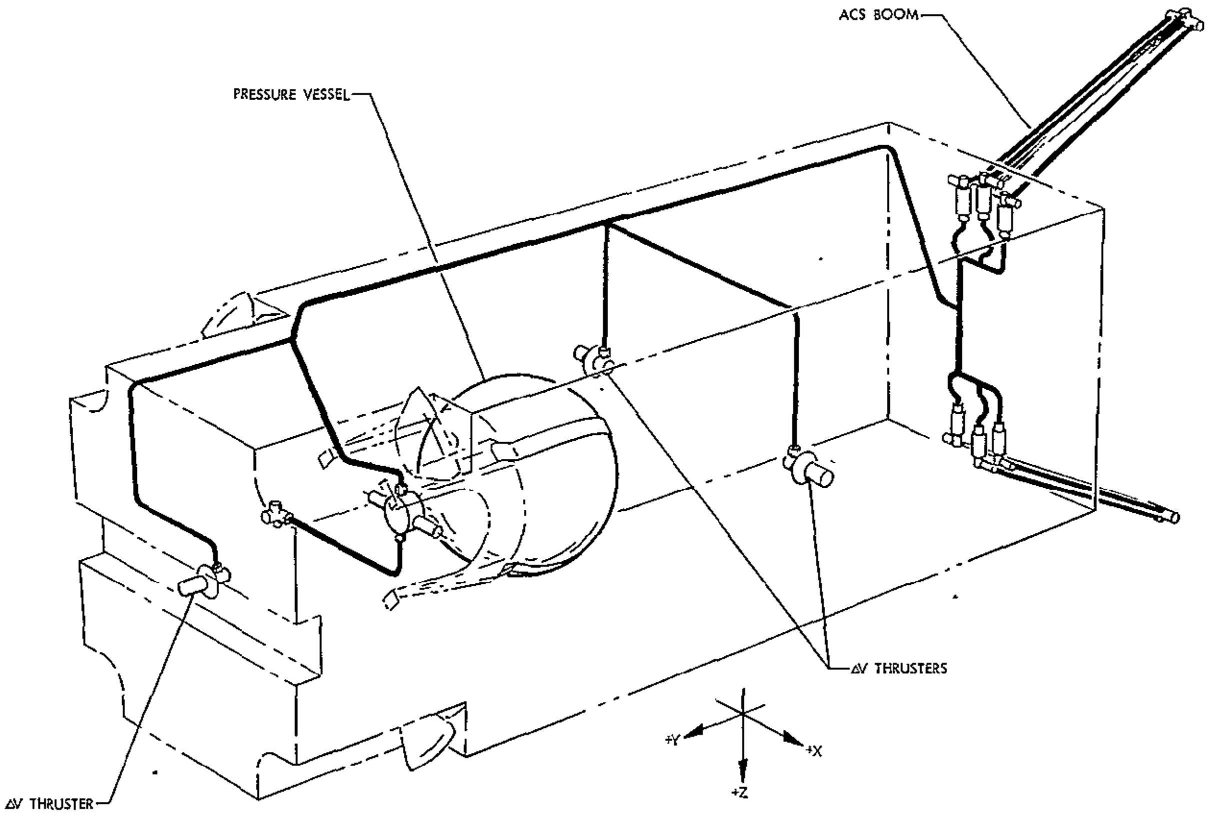


Figure 2-2

INSTALLATION OF THE ELECTROTHERMAL THRUSTERS is readily accommodated by the existing attitude control system

To correct the orbit which results from booster injection, the following actions are required:

- The orbit must be precisely measured by the unified S-band MSFN tracking network.
- The required correction in spacecraft velocity must then be computed. The required velocity increment must be computed together with points in orbit at which it is required.
- Given the required velocity and point of application, the time of thruster turn-on and turn-off must be determined from the

spacecraft ephemeris. NASA GSFC will provide this data to the OCC as the basis for the initial orbit adjustment.

- Commands for thrust generally will be executed by the spacecraft stored command programmer since real-time station coverage will probably be inadequate for the successive thrusting requirements. The specific commands for a thrust addition in the direction of the velocity vector are:

  CMD THRUST ARM, TIME TAG
  CMD +X THRUST ON, TIME TAG
  CMD +X THRUST OFF, TIME TAG
  CMD THRUST SAFE, TIME TAG

In general, the orbit adjustment function will require both in-plane and cross-plane thrustings. These may be carried out in the same time period. Two thrustings per revolution will have no unfavorable effect on any other system.

Only about two-thirds of the required velocity will be added to the spacecraft on the first correction. After completion of the adjustment, a second orbit measurement and velocity correction will be computed which may result in an iteration of the maneuver.

From orbital calculations, it appears that no adjustment in velocity will be required in the first year other than the initial series which may easily be completed in a week. In successive years, some trimming will be required if it is required that corresponding revolutions over the 18-day cycle track to a few miles. As discussed in Volume 2 of the Phase B/C Study Report, an adjustment of up to 17 ft/sec (cross-plane) is required to compensate for drift caused by solar gravity gradient across the orbit during one year. This torque on the orbit is compensated in the first year by an intentional 0.015 degree inclination of the plane to 99.098. The plane then drifts through the desired 99.083 degree inclination and beyond.

Once the observatory has been thoroughly checked out and the orbit has been circularized, the routine, on-orbit phase of operations begins.

2.3.2 Operations Planning

Operations planning involves the repetitive execution in the OCC of certain time- and function-oriented sequences to control the observatory,

payload, and ground facilities in the most efficient manner consistent with attainment of ERTS mission objectives. The OCC operations planning extends over a period of about 1 week prior to spacecraft contact. This is followed by operations scheduling to respond to weather and changes in spacecraft and ground system status.

2.3.2.1 Mission Planning

The criterion of success applied to mission planning is maximum responsiveness to user requests within spacecraft, payload, and ground system constraints. A high priority is placed on the establishment and maintenance of a sensitive and rapidly responsive system to reduce the elapsed time between user requests and satisfaction of the requests. High priority is also placed on the ability to translate requirements into a time-ordered sequence of events which at the outset expose the areas of conflict between user requirements and spacecraft capability.

The mission planning activity is initiated by assimilating all user requests, spacecraft ephemeris, and ground station coverage in the ADPE data base to produce a preliminary user request list.

A prerequisite data requirement for mission planning is a current and precise observatory ephemeris for utilization in determining when geographic areas of interest and ground station coverage will be within the range of the observatory. Observatory ephemeris will be made available from NASA on a weekly basis in the form of a digital tape reflecting the most recent NASA tracking data.

Preliminary sensor scheduling is predicated on the software generation of an acquisition table which correlates user sensor requests with observatory ephemeris predictions. The correlation creates a time ordered table of flagged geographic cell acquisitions on a basic earth grid. The interval over which the acquisition table is generated is determined by the OCC planner. For routine operations, it will be maintained over the cyclical 18-day interval (251 revolutions) and revised as ephemeris and user requests are updated.

Upon operator request, an initial time-ordered listing of sensor events for the period of interest is prepared. The preliminary user

request list does not expose conflicts since no constraints which could result in conflicts are considered at this point.

Having reviewed the preliminary user request list, the operator now demands a preliminary sensor event list based upon spacecraft, payload, and ground facilities constraints.

A cathode-ray tube display is presented to the planner, listing all potential user requests during the period of interest. Each request is translated into payload operating times (GMT) and identified according to priority. Conflicts in requested coverage are indicated by numerical descriptions, linking operating times for each individual request. Also available to the planner are printed tables which identify the conflicting user agencies and summarize the success of sensor data and imagery acquisitions for each requesting agency in preceding periods.

With all data before him, the planner may delete conflicting requests by a manual keyboard entry. Having thus reviewed and restricted sensor requests, the planner obtains an acceptable sensor event list (Figure 2-3). The resulting cathode-ray tube display indicates in temporal sequence the selected sensor operations, tape recorder usage, conflicting requests and, where possible, the nature of the constraint. The planner may alter priorities and seek a more satisfactory solution. In some cases he may, for example, alter the schedule for one orbital revolution in order to provide additional video tape recording capability during the following revolution.

2.3.3 Operations Execution

The activities required to coordinate personnel and ground facilities in order to command and control the observatory, acquire data, and perform analyses of the data comprise three distinct periods of operations which are orbitally time-dependent and together constitute operations execution phase.

2.3.3.1 Pre-contact Operations

Pre-contact operations are initiated 2 days prior to the scheduled contact between the observatory and ground facilities. This period is

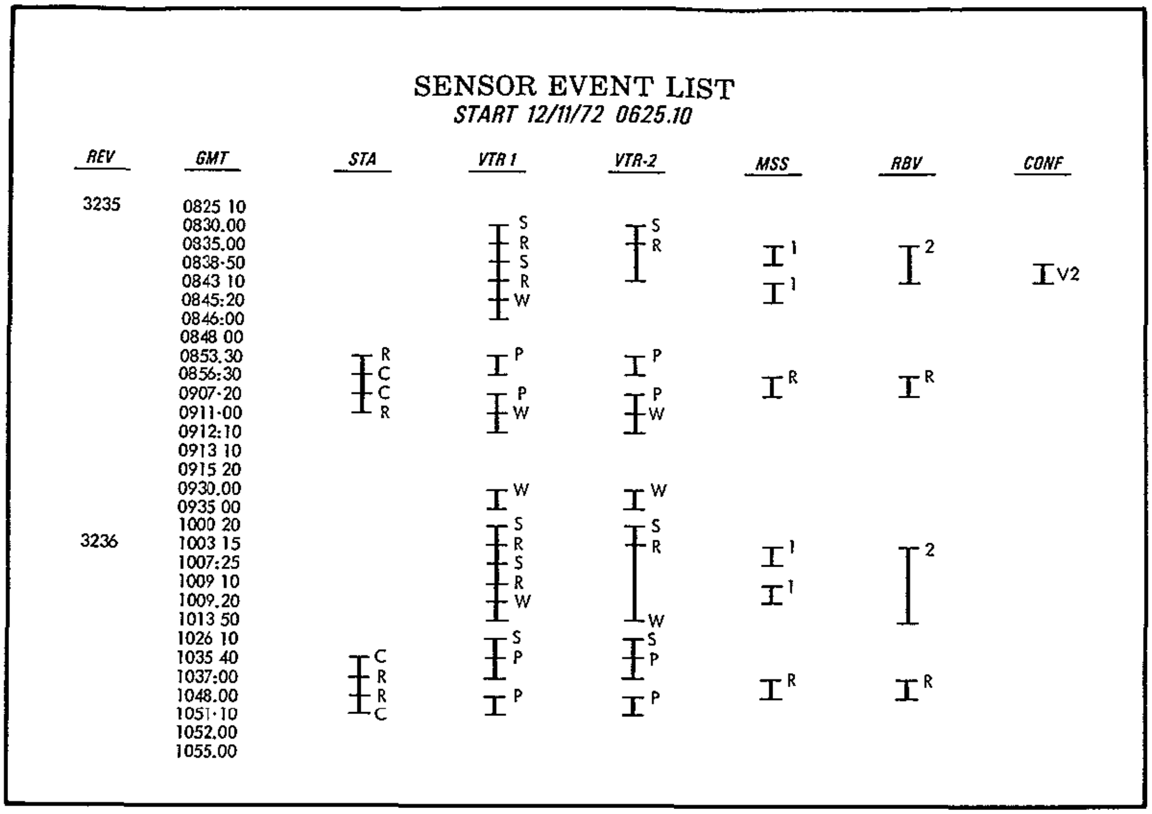


Figure 2-3

PRELIMINARY SENSOR EVENT LIST DISPLAY

characterized by making ready all personnel and ground facilities for the approaching contact and assignment of specific duties during the contact. It is during this period that the remote station is teletyped the pass assignment and advised of the type of telemetry data it can expect to receive from the observatory and in what manner it is to handle the data. Specific instructions are given concerning the real-time recording of all data and simultaneous transmission of housekeeping PCM data to the OCC. Additional instructions are given for post-contact replay of the housekeeping PCM and DCS data to the OCC and on labeling and mailing of recorded sensor data tapes to the NDPF for image processing.

The punched command tape is teletyped to the station along with the pass assignment. The tape reader/writer of the station teletype unit creates a command tape which is directly readable by the station command encoder and which will be retained at the station as a backup to be used at

the direction of the OCC controller in the event of loss of real-time command capability from the OCC. The full tape is immediately retransmitted by teletype to the OCC for assignment and command message validation.

2.3.3.2 Contact Operations

Contact operations begin approximately 45 minutes before the predicted time that the spacecraft enters the ground station antenna range, T-45.

T-45 to T-20 Activities

During this 25-minute period, all OCC personnel are at their assigned stations under direction of the operations controller. The command assignment is reviewed and error checked. The predicted commanded status of the spacecraft and payload in the ADPE data base is examined in light of the stored commands which have been executed since the last station contact. All hardware and operational software is readied and closed loop checked within the OCC. The command list is loaded into the ADPE memory, displayed, checked, and readied for real-time transmission.

T-20 to T_0 Activities

At T-20, NETCON is advised by telephone to bring on line the remote station, NASCOM data links, and SCAMA II voice line which were reserved by OPSCON during the operations planning phase. For the next 15 minutes the station-NASCON-OCC loop is tested and verified as shown in Figure 2-4.

- Pass Assignment. The pass assignment is verified over the SCAMA II line by the OCC command generation technician and the remote station controller.

- Command Translocation Test. Dummy commands are translocated over the high-speed data link to the station command encoder and reception is validated by the OCC ADPE.

- Uplink Command Transmission Test. Dummy commands are translocated through the station command encoder, uplink radiated through the antenna into a dummy load, and validated by the OCC ADPE.

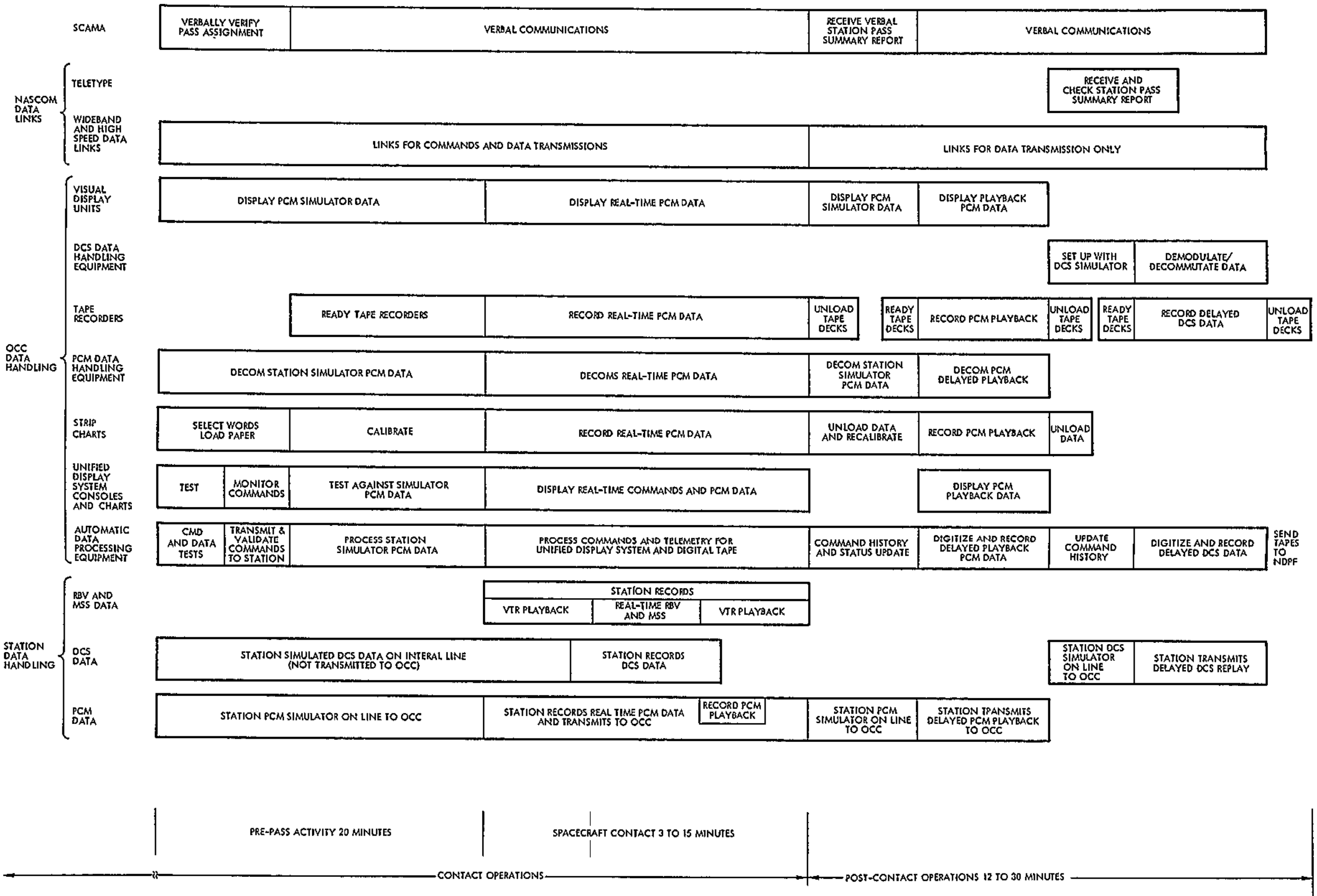


Figure 2-4

OCC AND GROUND STATION typical contact activity

- Command Translocation. The entire command list is translocated to the memory of the station command encoder and validated by the OCC ADPE as a backup precaution. The previously teletyped punched command tape residing at the remote station will only be utilized in the event of command translocation failure during this period. In that case, the command tape will be loaded into the station command encoder memory for transmission under the verbal direction of the OCC controller. Assuming no translocation difficulties, the command list stored in the station command encoder memory is switched off-line. The OCC ADPE, with its full command list retained in memory and displayed to the OCC controller, remains on-line ready for real-time transmission of commands through the station command encoder to the station command antenna.

- PCM Data Tests. The remote station places its PCM simulator on line over the NASCOM high-speed data link or wideband data link to the OCC. Remote station PCM data handling equipment, strip chart recorders, and visual display units are checked for operation using the simulator. Similar OCC equipment plus all software and their associated cathode-ray tube displays to be used during the pass will be exercised for readiness using the station simulated data. The station simulator will remain on line until removed at T-1 minute.

- DCS Data Tests. Pre-contact DCS data tests will be performed only by the NTTF since it is the only station capable of real-time transmission of DCS data to the OCC. The OCC DCS demodulator/synchronizer and data handling equipment will be exercised using the signal generated by the NTTF DCS simulator until T-1 minute.

- OCC Equipment Tests. Tapes are loaded into the tape recorder and tested for proper operating speed and signal levels. Strip charts are calibrated and data channels selected. Visual display units are checked for failed light elements.

Spacecraft Contact Activities

Operations during spacecraft contact will vary somewhat from pass to pass, depending upon the usage of the sensor while out of sight of the station and whether the pass is northbound (night) or southbound (daylight). In general, the command schedule shown in Table 2-2 will be typical for revolutions culminating in a 10-minute daylight station contact.

Through use of the on-board stored command programmer, all of the spacecraft and payload components which are to be utilized during the

Table 2-2. Typical Command Schedule for a 10-Minute Daylight Station Contact

Time	Command Type	Function
T_o		Acquisition of signal (AOS)
		Receive S-band signal, record at station
		Receive S-band signal, record at station Receive VHF signal, record at station } Relay PCM house-keeping data to OCC. OCC records.
T+00:15	RT	Initiate VTR playback on rising S-band AGC
T+00:30	RT	Initiate PCM housekeeping playback on rising VHF AGC, record at station
		OCC begins check of spacecraft and payload performance based upon display and software analysis
T+02:30	RT	OCC completes analysis and transmits corrective commands as necessary
		OCC permits 30-second ranging interrogation by MSFN tracking station
		OCC begins readout of stored command programmer
T+03:00		OCC completes readout of stored command programmer
	RT	OCC begins deletion of executed stored commands and loading of new stored commands
		Station begins reception of DCS data on S-band signal
		NTTF transmits in real-time to OCC
T+03:15	RT	OCC completes stored command loading and verification
	RT	OCC turn on RBV and MSS for warm-up
		PCM playback automatically halts and spacecraft record cycle begins
		Stop playback recording at station, begin tape rewind of reverse data
T+03:30		U.S. northern border crossing
	RT	OCC halts video tape recorder playback, station stops recording playback
T+03:3'	RT	OCC switches RBV and MSS to S-band transmitters, station receives and records real-time video data. NTTF transmits data to OCC for real-time imagery analysis
		Real-time commanding ceases
	SCP	Sensor picture taking events are cycled as scheduled in stored command programmer or Cameras remain on in real-time over continental U.S.
T+07:00		U.S. southern border crossing
		Stored programmer commands cease
	RT	OCC switches VTR's to S-band transmitters, station real-time video data recording ceases
		OCC turns OFF sensors
T+07:02	RT	OCC begins VTR playback, stations records
T+07:15		Loss of reception of DCS data on S-band signal
T+10:00	RT	OCC halts VTR playback on falling AGC, station stops recording
	RT	OCC turns off S-band transmitters, station stops recording
		Loss of signal (LOS)
		Lose VHF signal, station stops recording
		Lose S-band signal, station stops recording, halts data transmission to OCC
The commands loaded into the stored command programmer at T+3:00 will execute the following procedures out of range of the ground station:		
T+10:31	SCP	Rewind video tape recorders to prepare for recording
T+11:58	SCP	Halt video tape recorders
	SCP	Switch MSS and RBV to video tape recorders
The following sensor picture taking sequence will be repeated as scheduled by the stored command programmer:		
T+50:00	SCP	Video tape recorders to standby
		Turn on MSS and RBV
T+50:10	SCP	Video tape recorders to record
T+51:00	SCP	Turn off MSS and RBV
		Turn off video tape recorders
The following sequence will be initiated prior to and in preparation for acquisition by the next ground station:		
T-05:00	SCP	Rewind video tape recorders to prepare for playback
T-03:03	SCP	Turn off video tape recorders
T-03:30	SCP	Switch video tape recorders to S-band transmitters
T-01:00	SCP	Turn on S-band transmitters for warm-up
	SCP	Video tape recorders to standby to bring head up to proper speed
T_o		AOS - repeat above contact assignment

pass will be readied and warmed-up beyond range of the station. Upon first sighting of the observatory by the ground station, real-time commands will be transmitted to actuate the spacecraft communications system to obtain real-time housekeeping and DCS data, and video tape recorder playback. Payload data will be recorded at the ground station for later mail transmittal to the NDPF.

Immediately upon receipt in the OCC, real-time PCM data will be examined by the computer and displayed for quick analysis to determine the health and commanded status of the spacecraft. Any anomalous conditions detected will be corrected by real-time commands. As the spacecraft approaches the northern boundary of the U. S., video tape recorder playback will be halted and real-time RBV and MSS operations will commence. During this period, new stored command programmer commands will be loaded and executed commands will be deleted. As the observatory reaches the southern U.S. boundary, real-time RBV and MSS operations are halted and playback of video tape recorders recommences. As the spacecraft approaches the outer range limits of the station antenna, playback of the video tape recorders is halted and all real-time spacecraft operational equipment is commanded off. While out of sight of the ground station, the command list contained in the stored command programmer rewinds the video tape recorders in preparation for recording, performs the scheduled picture taking events, rewinds the recorders in preparation for playback at the next ground station sighting and readies the transmitters prior to the next real-time pass.

2.3.3.3 Post-Contact Operations

Post-contact operations are characterized by the assembly and processing of all data in the OCC. PCM playback data which was recorded at the 32 kilobit rate by the ground station during spacecraft contact is now replayed to the OCC at a slower speed of 8 or 16 kilobits, dependent upon the capability of the NASCOM link between the station and the OCC. During this period, all narrowband housekeeping PCM data is analyzed to assess spacecraft and payload performance. The PCM data is digitized by the ADPE and tape recorded for use by the NDPF. Immediately thereafter, the DCS data recorded by the station is similarly played back to the

OCC, digitized and transported to the NDPF. Finally, the command status in the ADPE data base is updated for those commands which will be executed by the stored command programmer while the spacecraft is out of range of the station. Update of real-time commands is unnecessary since the data base is updated automatically in real-time as commands are transmitted out of the ADPE.

The cycle from mission planning through data acquisition and analysis is now complete, only to be repeated on a routine basis.

2.3.4 Command Generation

The command generation function transforms the approved observatory event list into an encoded command message ready for transmission to the command station. The command generation sequence, illustrated in Figure 2-5, begins after the final event list is prepared.

A complete command library listing all commands available for controlling the observatory and sensors is structured within the OCC computer. A command list is automatically assembled from the input table of observatory event sequences. Command functional checks and block checks are performed to insure against any constraint violations.

The command message is automatically formatted with proper real-time and stored command formats and unified S-band or VHF formats. Each command is assigned a decoder and internal address along with a stored command programmer address, if needed. The OCC computer then assembles the command sequence into a command message in a form compatible for transmission (high-speed data link, teletype or voice) to the remote station. Command formats for real-time and stored commands are presented in Figure 2-6.

The detailed command list is then presented to the command console controller on a cathode-ray tube display. This display provides the operator with real-time control over command generation and transmission as well as immediate detailed feedback on the processing, transmission, and validation. A representative command display format is shown in Figure 2-7. The display page heading provides basic information containing observatory identification, acquisition station, date, revolution,

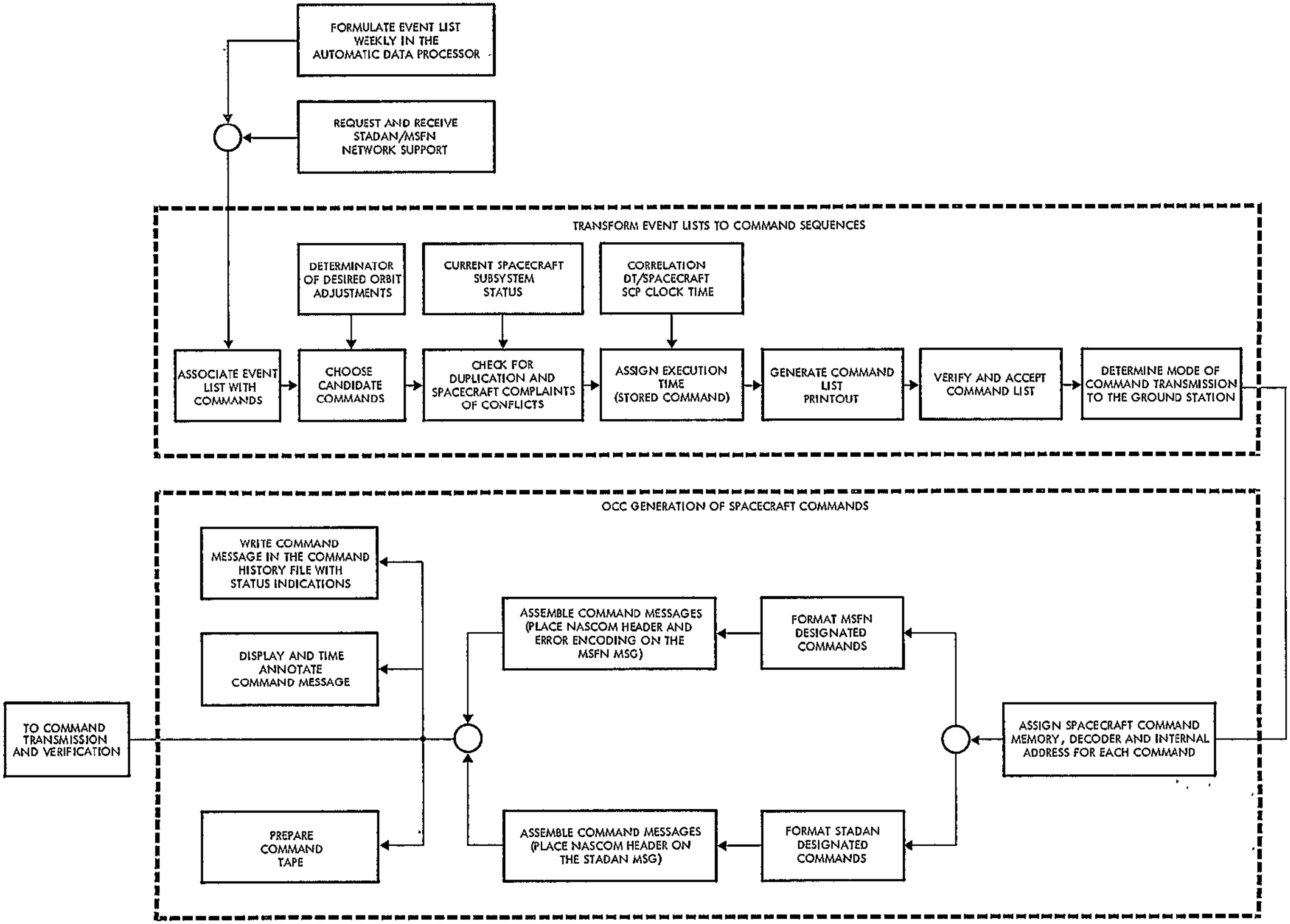


Figure 2-5

COMMAND GENERATION functional flow

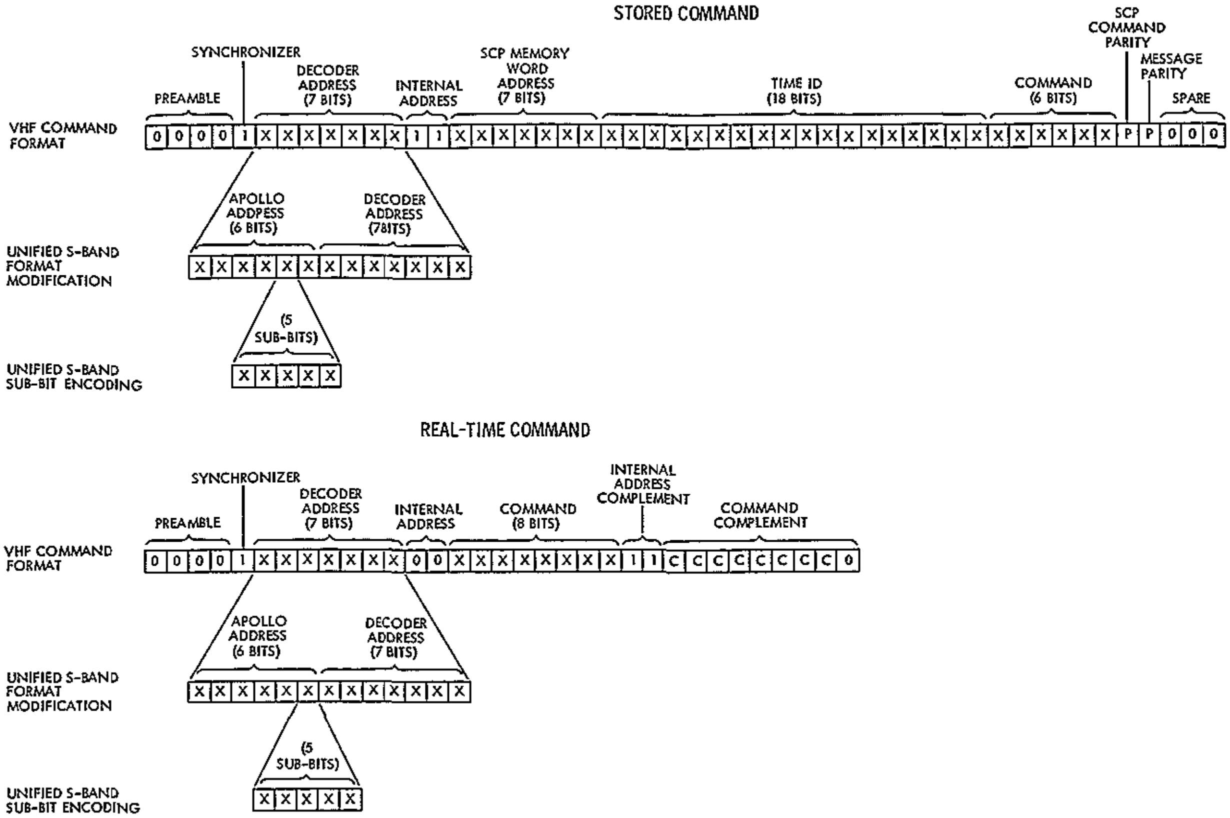


Figure 2-6

COMMAND FORMATS

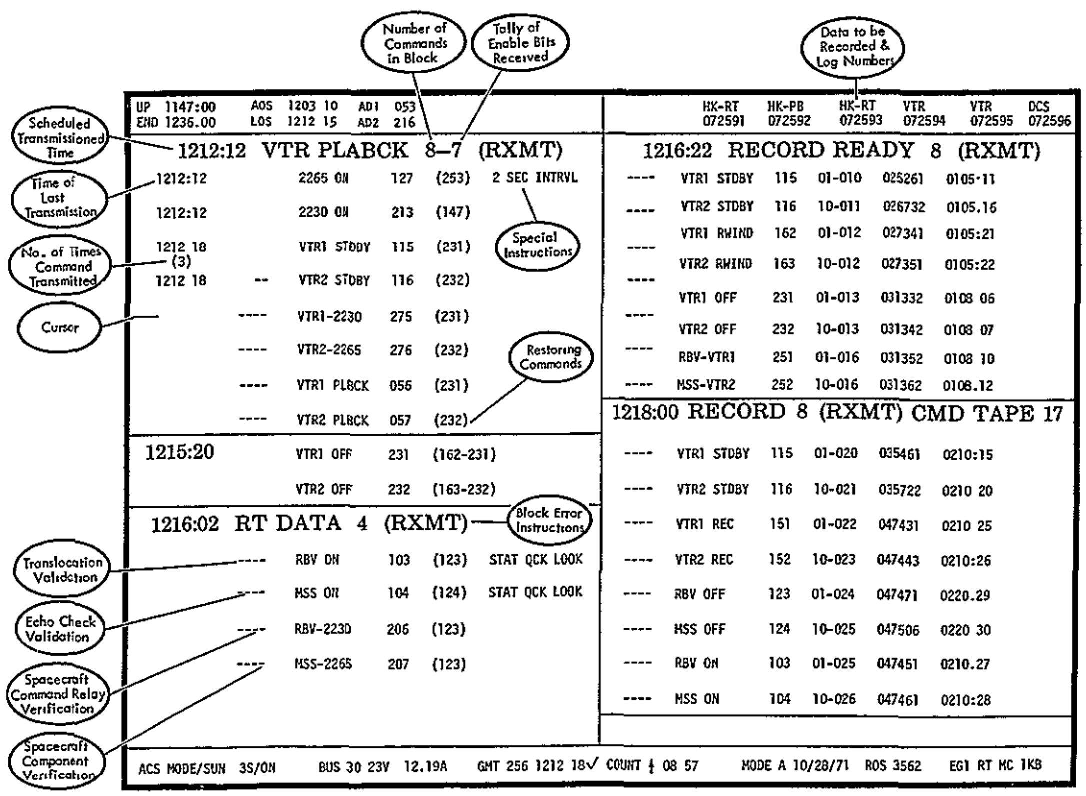


Figure 2-7

TYPICAL COMMAND DISPLAY

observatory address, number of command pages, voice link up-time, predicted spacecraft acquisition time, predicted loss of signal time, voice down-time, command generation mode, data to be recorded at the station, and associated tape identification numbers.

The command list is divided into blocks of commands. Each block is enabled separately by operator action. An identifying heading for each block denotes the function of each command block, scheduled time for start of transmission, number of commands, and a reference instruction for contingencies. Each line in a block of real-time commands gives the command literal, octal code, a referenced command number of contingency (restoring the prior state), and a space allocation for special instructions. As the block of commands is transmitted, the time of transmission appears at the left of individual commands together with information on the current status of validation and verification checks.

The message is written on magnetic tape for subsequent transmission to the command station as well. On option, the command message may be output on punched paper tape suitable for transmission via teletype. This option provides a backup mode of command message transmission.

A slightly different format is employed for nonreal-time commands to the stored command programmer. Actual time of transmission of individual commands is not displayed, nor are enable bits received to provide a count in the block header. Each stored command listing includes its stored command programmer and slot address, observatory clock execution time (octal), and GMT execution time.

Several lines are reserved at the bottom of the display for manual insertion of the octal code for unscheduled commands which must be sent to deal with unforeseen contingencies.

2.3.5 Command Transmission and Verification

The command message is transmitted to the ground stations in a computer-direct mode. In this mode the OCC computer functions as a command encoder, outputting data for transmission via the NASCOM high-speed data lines.

Each command message received at the remote site will be verified at the OCC before transmission to the spacecraft. Also, command execution in the spacecraft will be telemetered to the ground stations and sent to the OCC, where the command is verified in the computer. The executed commands will be compared with the command list and any dropouts or failures will be corrected.

The overall function flow for command transmission and verification is shown in Figure 2-8.

2.3.5.1 Command Transmission

The command message may be transmitted by the OCC computer or by teletype. The prime mode utilizes the OCC computer functioning as an encoder.

The operator normally calls up the command display (Figure 2-7) 20 minutes before scheduled observatory acquisition time to review the scheduled command sequence. When reliable observatory communications have been established, the operator can begin command enabling. A cursor appears at the left of the heading of the first block of commands when the display is called. Actuation of the enabling control on the console starts the automatic sequential transmission of the commands in the block. The cursor is automatically positioned to indicate the command being transmitted. The actual transmission time is displayed and command validation and verification check indications are inserted in the display as received at the OCC computer. Validation and verification failures are indicated by a symbol in the appropriate column which blinks to attract operator attention. In the event of a failure to verify, a command is automatically retransmitted. If validation is not achieved after the third transmission further attempts are automatically halted and the operator is alerted to intervene manually. When a block of commands has been transmitted the cursor is positioned at the next block heading to indicate that the operator may enable the next block.

At the conclusion of the station pass, the command list display contains a full history of commanding operations which is recorded in a hardcopy output for the permanent record and historical file.

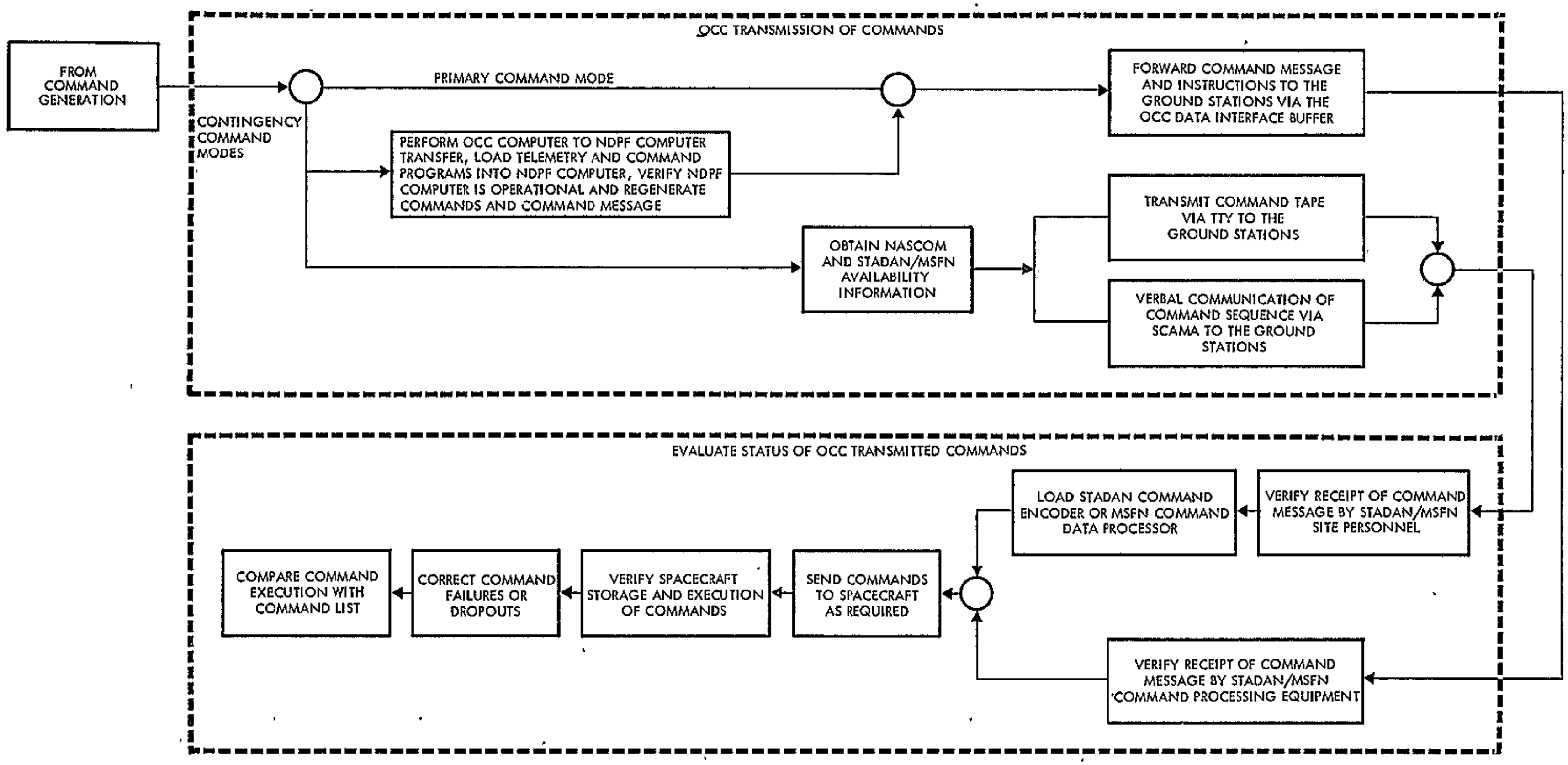


Figure 2-8

COMMAND TRANSMISSION AND VERIFICATION functional flow

The command data flow through the GDHS is illustrated in Figure 2-9. The command message is routed through the OCC data interface buffer for translation into a serial 600-bit message block for transmission to the remote stations via the high-speed data lines. The buffer output is transferred at 50 kbits/sec through data modems to the modified communication line termination which shifts data in 600-bit blocks into the NASCOM switching computer at GSFC. After automatic routing through the communication line termination, the blocks are transferred to the remote station at 2.4 or 4.8 kbits/sec. The high-speed data lines are full duplex so that transmission by the ground stations to the OCC follows a similar but unconflicting return path.

Since the STADAN and MSFN command systems are different the command message received by each station required different handling. In the case of the STADAN stations, the data transmission system decoder temporarily stores the incoming serial data at the high-speed data bit rate and clocks parallel data out to the station command encoder at its required rate. The STADAN station encoder stores the properly formatted command, including execution time, in its 40 kilobit memory.

At the MSFN station the incoming serial message is clocked by the data transmission unit and transferred in parallel to the command computer for storage in its 60-kilobit memory.

All commands transmitted from the station to the observatory originate in the station command encoders or command computer and are radiated through the station antennas. The source of these commands can be a real-time transmission of a command message from the OCC, a punched tape, or a manual keyboard entry.

In the event of partial or total loss of data lines to the remote station the message is sent via teletype. The NASCOM teletype network provides a duplex system for this command transmission mode. The punched tape command message output from the OCC computer can be loaded directly into the teletype to produce an identical tape at the receiving terminal.

Voice communication via SCAMA II provides a second operational backup mode for command transmission. Upon OCC verbal direction,

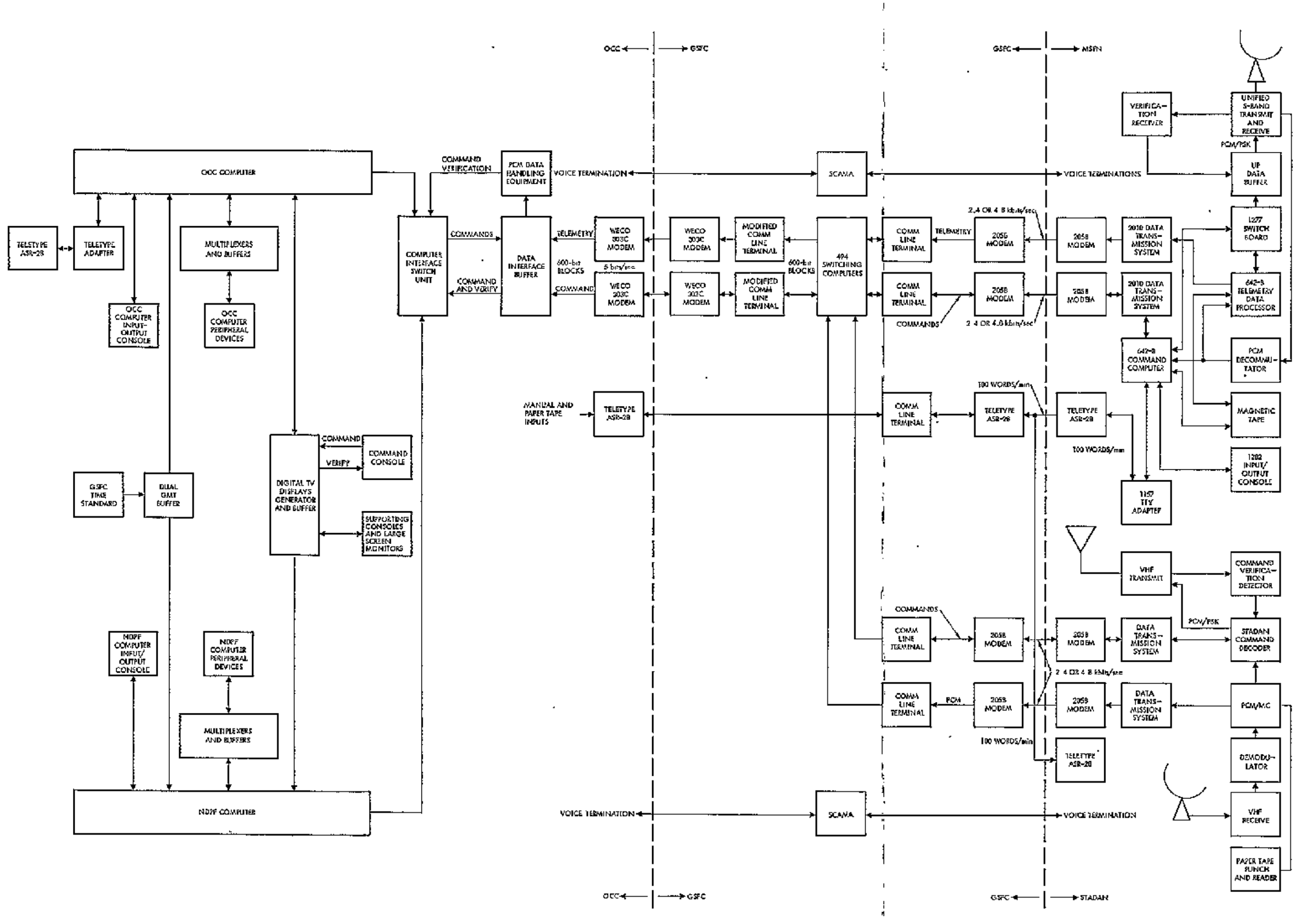


Figure 2-9
COMMAND GENERATION EQUIPMENT block diagram

FOLDOUT FRAME 1

FOLDOUT FRAME 2

remote station personnel manually enter command messages into the station command encoder.

2.3.5.2 Command Verification

To obtain assurance of error free transmission, the command message is validated at every opportunity along the transmission route.

- In the OCC, the command console operator reads the command message memory prior to transmission.
- Upon transmission, the OCC data interface buffer feeds the message back to the computer for a bit-by-bit validation.
- At STADAN sites, the command encoder receives a command, retains the command in memory, and retransmits the command back to the OCC for a bit-by-bit validation comparison. If the validation fails, transmission will be halted and the OCC command monitor will be signaled for intervention. When the command is validated, the OCC computer will transmit a validation flag to the station encoder for that command. The MSFN incorporates a higher order of validation, utilizing error encoding, 6-bit vehicle address check, and command word bit structure comparisons. If invalidated, an OCC retransmission of the command is automatically demanded. If invalidated after the third transmission, the transmission is halted automatically and manual intervention is required.
- At all stations, the command encoder or command computer performs a bit-by-bit detection and validation of the radiated command which is returned via a receiver mounted on the command antenna. A detected error will be signaled on the encoder panel and command transmission will be halted immediately.

In addition to transmission validations, functional verification is obtained by examination of the spacecraft telemetry. Acceptance of a command by the spacecraft is indicated by an enable bit. Execution of real-time commands is verified by commanded relay status changes, stored programmer commands by readout of the entire stored command load, and other commands (where possible) by functional changes in the commanded observatory components. Cathode-ray tube displays, printouts, and strip charts present the verification data visually.

2.3.6 Observatory Monitoring

Observatory status, health, and command response are monitored by the computer for out-of-tolerance conditions and by the OCC operating personnel through the use of computer aided displays.

The computer provides the bulk of the PCM data monitoring by comparing current values with prescribed limits as well as the preceding frame and issuing an alarm when an out-of-limit or any other anomalous condition exists. In this way, the computer serves as a sentinel to alert operations personnel of potential failures and critical conditions detected in the telemetry data stream.

Readout of specific subsystem data values is available at the terminals of the unified display system. The display parameters are functionally grouped according to observatory subsystems. Examples of display formats are presented in Section 2.4.2.4.

Provision is made for backup display of PCM data independent of the OCC computer. Digital readouts of selected parameters in octal form are read directly from nixie tubes on the decommutation equipment. This equipment also outputs data to six strip chart recorders allowing continuous monitoring of 48 additional parameters.

2.3.7 Payload Utilization

The observatory payload will be scheduled to optimize user requests within the constraints posed by consideration of observatory health, sensor characteristics, ground support and weather.

2.3.7.1 Sensor Operations

Sensor output is telemetered in real-time via wideband links or stored in two identical tape recorders for later replay. Thirty minutes of data may be stored in each recorder. Payload operation and tape recorder playback is dependent on the satellite ground trace and location of the ground stations. A sample schedule of sensor and recorder operations, compiled for a typical daily ground trace assuming dedicated coverage from the primary ground stations (Rosman, NTTF, Corpus Christi, and Alaska), was arbitrarily initiated at a longitude of 135°E. The corresponding station pass acquisition and duration times are identified in Table 2-3, assuming a 5-degree minimum elevation angle.

Camera operating times for global coverage are based upon the assuption that: 1) pictures would be taken over continental land masses

Table 2-3. Station Acquisition Schedule

Revolution Number	Station	Station Acquisition Time* (hr:min:sec)	Pass Duration (min)
2	NTTF	02:18:00	13.9
2	Corpus Christi	02:22:25	10.7
3	NTTF	04:00:55	11 1
3	Corpus Christi	04:02:50	13.7
4	Alaska	05:37:00	11 8
5	Alaska	07:18:50	14.3
6	Alaska	09:01:05	13 8
7	Alaska	10:42:55	11.8
8	NTTF	12:11:35	7 7
8	Alaska	12:23:50	10.6
9	NTTF	13:49:25	14.2
9	Corpus Christi	13:50:00	11 1
9	Alaska	14:03:35	11.5
10	Corpus Christi	15:30:10	13.5
10	NTTF	15:35:10	7.5
10	Alaska	15:43:25	13 4
11	Alaska	17:24:35	14 2
12	Alaska	19:08:05	12.7
13	Alaska	20:55:50	5.8

*Station acquisition time measured from ascending node of first revolution.

only, 2) no pictures would be taken over polar regions or Greenland, and 3) the RBV and MSS cameras operate simultaneously. Video tape recorder readout, if needed, is assumed throughout station acquisition except during real-time camera operating intervals. The resulting operating times are listed in Table 2-4. For accounting purposes, it is assumed that the video recorders were initially full.

The sensor data of Table 2-4, corresponds to a single daily operating schedule and does not reflect variations in the ground trace throughout the

Table 2-4. Sensor Operating Schedule - Global Coverage

Revolution	Event Location	Station Contact	Record Time (min.)	Playback Time (min.)	Real-Time (min.)
1	South America	--	0*	0	0
2	Canada, South America	NTTF, Corpus Christi	8	10	5
3	Canada, U.S., Mexico	NTTF, Corpus Christi	0	2	12
4	Canada, U.S.	Alaska	4	5	7
5	Canada	Alaska	0	11	3
6	Alaska	Alaska	0	10	3
7	Asia, Australia	Alaska	6	4	4
8	Asia, Australia	NTTF, Alaska	17	6	0
9	Asia	NTTF, Alaska	17	11	0
10	Asia	Corpus Cristi, Alaska	15	23	0
11	Asia	Alaska	19	14	0
12	Europe, Africa	Alaska	23*	13	0
13	Africa	Alaska	6*	6	0
14	--	--	0*	0	0
		Totals	115	115	34

*Denotes recorder full.

complete 18-day cycle. Average results over an entire 18-day cycle are summarized below:

	Min./Day
Picture-taking opportunities	156
Station coverage	184
Recorder playback time	108
Real-time readout	33

The above data indicate that the MSS could fill a single tape recorder during an average operating day. The MSS can operate a maximum of 141 minutes per day (33 in real-time and 108 in record mode) and could therefore miss an average of 15 minutes of picture-taking opportunities

per day due to recorder capacity. The RBV cameras, however, do not require as much recorder capacity per picture and can operate the full 156 minutes per day (33 in real-time, 123 in record mode).

The preceding sensor operating times do not include cloud coverage considerations and should, therefore, be considered as a "clear day" upper limit. Inclusion of a cloud coverage prediction capability significantly reduces picture-taking opportunities. It can therefore be concluded that, practically speaking, video tape recorder capabilities will not restrict global picture-taking requirements.

2.3.7.2 Stored Command Programmer

Two redundant stored command programmers are utilized for command execution independent of ground station viewing. The stored command programmer receives commands and corresponding time tags via the command link, stores the commands, and executes them at the time defined by their time tags. Each programmer may store a total of 127 usable command words plus one sync word. Each command word is 25 bits in length consisting of 17 bits for time tag, seven for the command, and one for parity. The 17-bit time tag results in a 20.97 hour cycle time. After this time the commands remaining in the stored command programmer memory will be repeated.

The stored command programmer contents are scanned every 64 msecond and comparison is made between the time counter and the time bits within each stored word. When a time coincidence is recognized, the stored command is transferred serially to the digital decoder for execution.

Stored commands will also be utilized for sensor warmup and operation for real-time passes. Warmup commands are to insure the cameras are ready for use as soon after station acquisition as possible and camera events will be commanded by stored commands to allow more precise control over shutter times than could be obtained by ground commands.

The programmer will be loaded for several revolutions. This provides the capability of insuring that in the event a command station is lost, video data may still be obtained.

2.4 PCM TELEMETRY AND DCS DATA HANDLING

Processing of PCM and DCS data consists of the operations required to produce values in engineering units available for display, strip chart records, forced messages, flagging of anomalous conditions, printed hard-copy, and a tape of DCS data. The major steps in PCM and DCS data processing are:

- Receipt of DCS and housekeeping data
- Decommutation of DCS and housekeeping data
- Computer processing and monitoring of housekeeping data
- Display of housekeeping data
- Generation of computer tape of DCS data.

2.4.1 PCM and DCS Data Preparation

The PCM data handling equipment accepts DCS and housekeeping PCM data from remote sources. These data are either processed immediately or stored for later handling. Outputs are provided to the computer and to analog recorders. Provisions are made for readiness testing using built-in equipment with computer control. Control and programming of PCM data handling normally resides in the computer with a minimum of human intervention. However, full manual capability is possible. Figure 2-10 is a simplified block diagram of the equipment.

The PCM data handling equipment provides the following functions:

- Accepts housekeeping PCM and the DCS intermediate frequency from ground stations
- Provides tape recorder storage for all incoming data to the OCC
- Conditions data for decommutation
- Decommutates conditioned PCM, provides parallel data to the OCC computer, provides drive for strip chart recorders
- Provides operational backup for computer using internal display functions
- Accepts processing programs and control from the OCC computer.

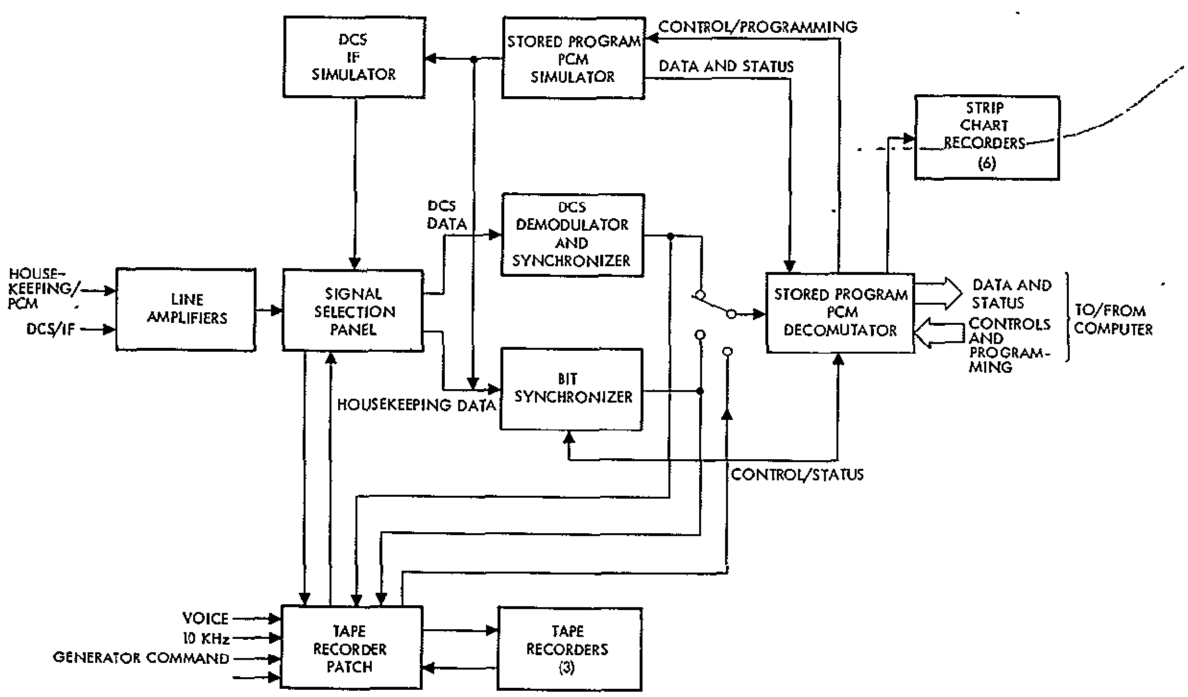


Figure 2-10

PCM DATA PROCESSING simplified block diagram

A number of basic modes of operation are employed:

- Process real-time housekeeping PCM (HK-RT)
- Process data by playback from distant stations
- Process stored data from the spacecraft (HK-PB)
- Process the DCS spectrum, generally not in real-time
- Simultaneously accept any or all of HK-RT, HK-PB and DCS, provide on-line processing of HK-RT or HK-PB with temporary storage of the others
- Self-verification
- Programming by computer, punched tape or manual (including changes to existing programs) concurrently with or separate from normal operations.

2.4.1.1 Formats

The data input has basically two forms, housekeeping PCM and DCS data, as listed in Tables 2-5 and 2-6.

Table 2-5. PCM Data Handling Formats for Housekeeping PCM

At Observatory	At Input	At Output
75 kHz IF with a bandwidth of 100 kHz. Not recorded or processed on the observatory. The 110-bit messages are formed as follows: Bit rate· 2 kbits/sec ±2 percent Modulation: PSK (±90 degrees) Preamble· 25 bits Sync: 3 bits DCP address· 10 bits DCP data: 8 words of 8 bits Error code: 8 bits	From NTTF· 75 kHz IF. Bandwidth 100 kHz From Alaska· 1/8 speed playback (9.4 kHz) of IF over wideband link. Bandwidth 12.5 hKz.	To Computer: Same as for observatory PCM, except 8 bits per data 10 bits for address

Table 2-6. PCM Data Handling Formats for DCS Data

At Observatory	At Input	At Output
Word: 9 bits long Code: Biphase Frame: 128 words (1152 bits) Subframes Three of 128 words each Bit Rates (10^{-6} stability): HK/RT-1 or 32 kbit/sec HK/PB-32 kbit/sec HK/1-1 kbit/sec HK/2-1 kbit/sec Definitions: HK/RT - Real-time PCM HK/PB - From narrowband PCM recorders (2) HK/1 - - From narrowband track on video tape recorder 1 HK/2 - From narrowband track on video tape recorder 2 Note· HK/1 and HK/2 are not processed in the OCC but are recorded on auxiliary tracks on the MSS and RBV recorders at receiving ground stations	From NTTF: as received from the observatory (biphase) From NASCOM highspeed data link via data interface buffer at 1054 kbit/sec (NRZ-c). All NASCOM header and fill stripped down to observatory frame format format. From NASCOM wideband link (Alaska/Rosman) 1, 16, 32 kbit/sec depending on mode, otherwise as received from the spacecraft Note: HK/PB is LSB first since reproduction is on rewind and data is thereby reversed.	To computer Data: 9 or 18 parallel depending on data handling equipment program (maximum of two buffer registers of 37 bits) Data tag 11 bit parallel bits. Other: Controls and status constituting the normal interchange of signals between the data handling equipment and computer to achieve an adequate relationship To strip chart recorders Analog signals representing telemetry words. 32 channels maximum by data handling equipment program, 20 channels max by manual selection on data handling equipment. Normally divided in ratio of 24/12 with 8/4 spare.

2.4.1.2 Programming and Control

The OCC computer originates the majority of programs used by the PCM data handling equipment, relieving operators of this task. It also makes rapid changes in programs and selects the particular program to use. The equipment can store as many as 10 such programs and is flexible enough to permit the computer to insert or make changes to any program while another is currently in use.

Such an interchange with the computer results in expeditious and efficient handling of data from various ground stations with little operator intervention; however, always present is the need for contingency operation. For this reason, the data handling equipment retains full manual capability for backup purposes. Even though such manual capability is restricted in terms of throughput and processing detail, it would be entirely possible to safeguard the satellite in event of a computer outage.

PCM data handling equipment as described above is defined by NASA Specification S-534-P-6. Typical equipment meeting this specification is the Dynatronic SPD-501, which has been supplied to several STADAN ground stations.

To achieve economic utilization of equipment, many items are time-shared between the housekeeping and DCS functions as shown in Figure 2-10. The rationale is that DCS is not basically real-time so far as the OCC is concerned. Therefore, the largest (and most expensive) item, the stored program PCM decommutator, handles either data as scheduled, with real-time housekeeping having priority. Such things as tape recorders, switching and patching are correspondingly shared. The stored program PCM simulator is also shared, but this is an off line function.

2.4.1.3 DCS Data

The handling of DCS data presents a unique problem by virtue of the special nature of the input data, i.e., the 75 ±50 kHz IF spectrum. The requirement to convert these random multiplexed data into a synchronized bit stream which can be handled by the PCM decommutator is met by the DCS demodulator and synchronizer.

The decommutator is the focus of all DCS data and housekeeping data entering the OCC. Since the DCS data are not real-time (except from NTTF), the decommutator is time shared with housekeeping data, the latter normally having priority. The need for a flexible system indicates the use of a stored program decommutator working under computer software control. Equipment that meets the requirements of NASA Specification S-534-P-6 in this respect is particularly applicable to the OCC. The fact that such equipment has slightly excessive capabilities in terms of bit

rates, frame length and certain outputs does not affect its applicability to ERTS.

2.4.2 PCM Data Processing

PCM data processing consists of those computer operations performed on the PCM housekeeping data subsequent to PCM data preparation as discussed in Section 2.3.1. The results of this processing are a current data base, historical files, trend files, cathode-ray tube display outputs, and printed pages. This processing occurs on-line as the data are received from the observatory or as playback data are received from a remote station or from the OCC tape recorders. It occurs at either the standard data rate of 1 kbit/sec or the accelerated rate of 32 kbits/sec. The PCM data processing provides the following features:

- Data checking - Every data word designated as significant is automatically evaluated against criteria established by engineering test, analyses and operational experience.
- Monitoring by exception - Operations personnel are alerted when pre-established criteria are violated.
- Meaningful data - All data are presented in readily usable form. Analog data are presented in engineering units.
- Availability of data - Every data parameter is readily available for viewing. Data fields are selectively updated as values change.

This processing involves four distinct activities: preliminary processing, data evaluation, data base update, and data display.

2.4.2.1 Preliminary Processing

In preliminary processing incoming telemetry words are compared against the corresponding words of the previous frame. No further processing occurs on a word that is unchanged from its previous value. If, on the other hand, a change in values is detected, the data word is placed in a working table for further processing. Preliminary processing occurs at a rate to insure that no data are overwritten in the buffer without being checked.

2.4.2.2 Data Evaluation

Data evaluation occurs on those telemetry words that have changed from their previous values, i.e., the contents of the working table. This

activity is directed by a telemetry processing matrix that specifies the processing for each word and contains the evaluation criteria. The types of processes that can occur are delta checks, warning level checks, critical level checks of analog data, and bit configurations checks for discrete parameters. Appropriate tags reflecting the results of these checks are affixed to the data.

2.4.2.3 Data Base Update

The data base is updated to reflect the new value. The new values are converted to engineering units, data are placed in the trend files, and a history file of all data is updated.

2.4.2.4 Data Display

PCM data processing also includes the display of data through the unified display system and line printer. All data points of the PCM telemetry stream that contain information relating to the observatory and payload subsystems are processed for display. Data is presented to the operators through the unified display system in the following ways:

- Preformatted subsystem displays
- Forced messages
- Trend lines.

The basic form of PCM information display is a set of predetermined formats that are called up by operations personnel through console keyboards. The data are organized by observatory subsystem. Formats for the following observatory subsystems are described in Section 2.4.2.5:

- Electrical
- Attitude control and velocity correction
- Communications
- Structures deployment
- Data handling
- Thermal control
- Stored command programmer

- Video tape recorder
- Multi-spectral scanner
- Return beam vidicon
- Data collection system.

In addition, a special predetermined format consisting of key parameters of each subsystem provides summary information for the entire observatory.

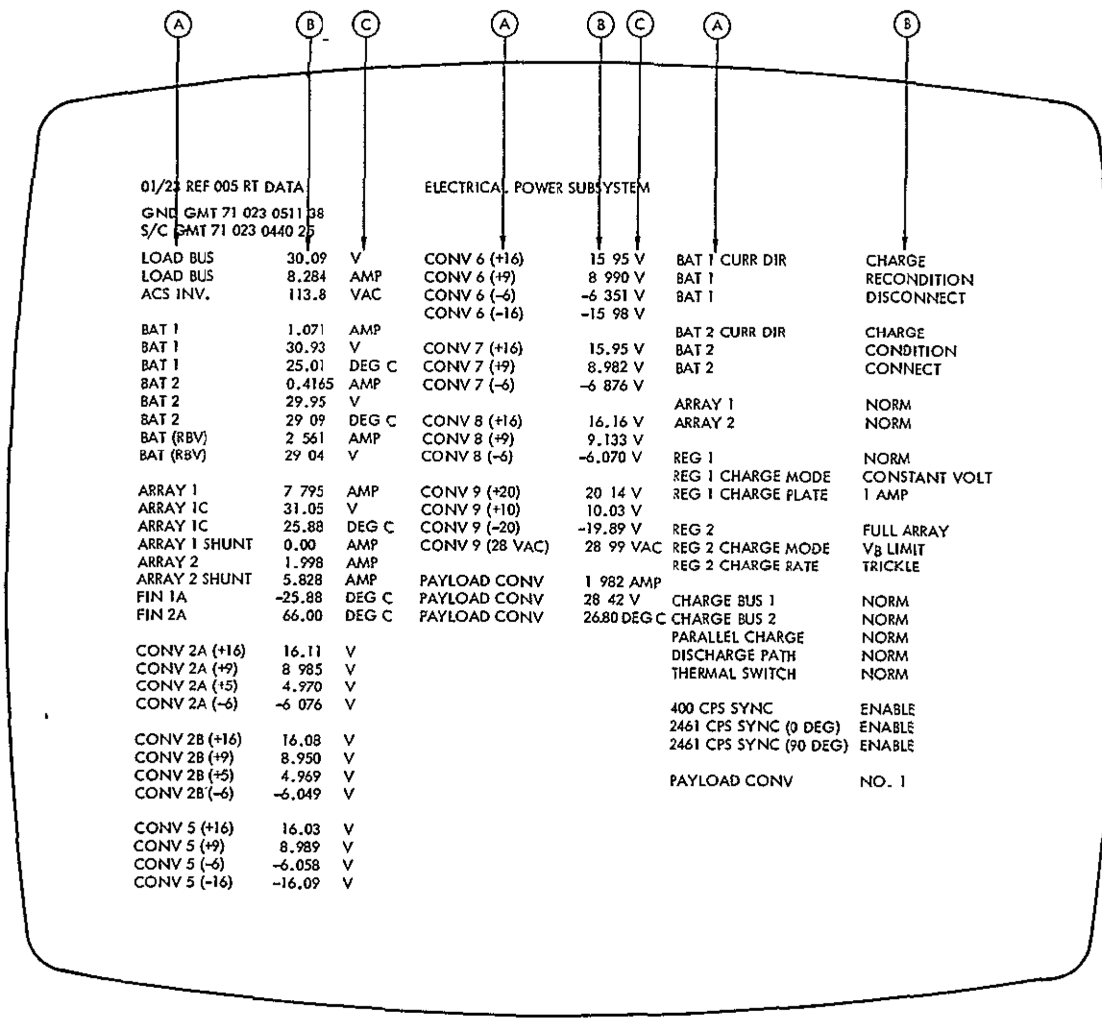


Figure 2-11
ELECTRICAL POWER SUBSYSTEM display format

Consider, for example, the predefined display format shown in Figure 2-11, which shows the status and configuration of the electrical power subsystem. Parameter literals are shown in columns labeled A,

the value (or state, for discrete parameters) is in the columns labeled B. Units are shown in the columns labeled C.

These predefined formats can be called to any cathode-ray tube surface within the OCC by operator request through his associated console keyboards. A copy of any displayed image in the form of an 8-1/2 x 11 inch sheet can be obtained from a hard-copy printer upon keyboard request.

Historical trends of selected PCM parameters are available as graphical plots on the cathode-ray tube surface. A rapid access trend file, which resides in core storage, is formatted and displayed for near-real-time analysis. Long-term trend data are retrieved from an off line tape file and processed by a curve fitting routine for display.

Another form of PCM data display is based upon warning or critical conditions that must receive early or prompt attention. An example of such a message is shown in Table 2-7. The forced messages appear on the displays without the need for request when this mode of operation is initialized by the affected console positions. Alternatively, the operator may condition his console by keyboard request not to have a forced message replace the display that is in view, but to signal its presence by a flashing discrete indicator on his control panel. Operations personnel request subsystem display images appropriate to the condition; for example, the electrical power subsystem display format. Further, historical trend plots can be obtained of the anomalous parameter(s) from the rapid access or long-term trend data files.

Table 2-7. Warning and Critical Messages

Telemetry Ident	Literal	GMT Spacecraft Clock	Current Value	Warning L H	Critical L H
D8	Battery 1 volts	021 0509 41	25.00	28.00/32.00	26.00/32.00
D6	Battery 2 volts	021 0315 14	27.72	28.00/32.00	26.00/32.00

A complete description of the unified display system is given in Section 4 of this volume. In addition to supporting control center contact

operations as described thus far, the unified display system permits any console to receive quick-look RBV imagery and MSS waveforms (A-scan) displays. The unified display system, by means of its interactive displays, keyboards, and tracking cursor also provides the subsystem and planning analysts to accomplish their tasks with computer assistance.

Inherent in the OCC design is the capability to monitor, in a contingency mode, selected key observatory parameters without the benefit of the processing described in this section. Thus, if the computer system becomes unavailable due to malfunction, operational cognizance of the internal observatory situation is still available. This is provided by outputs inherent in the PCM data handling equipment. A continuous record on a strip chart can be made for selected parameters; in addition, telemetry words can be selected for readout in octal form. Approximately 20 percent of all housekeeping parameters can be monitored in this manner.

2.4.2.5 Display Formats

Display formats for PCM housekeeping data are illustrated in Figure 2-12 through 2-18. Two character sizes are provided for headings and text. Attention is directed to specified descriptors by character and word blinking.

01/23 REV 005 FT DATA	ATTITUDE CONTROL SUBSYSTEM		
GND GMT 71 023 0511 38			
S/C GMT 71 023 0440 25			
GAS HIGH PRESS	2871 PSIA	SUN ALARM SIGNAL	NO SUN
GAS LOW PRESS	49.5 PSIA		
GAS BOTTLE TEMP	18 0 DEG C	TRACK CHECK (HEADS)	A B C D
PITCH ERROR	-.1018 V	GAS CONTROL VALVE (1)	OFF
PITCH WHEEL COUNT	0.0 RPM	GAS CONTROL VALVE (2)	OFF
PITCH WHEEL TEMP	21.0 DEG C	GAS CONTROL VALVE (5)	OFF
PITCH RATE GYRO DEMOD	0.0 V	GAS CONTROL VALVE (3)	OFF
PITCH RATE GYRO TACH	0 0 RPM	GAS CONTROL VALVE (4)	OFF
		GAS CONTROL VALVE (6)	OFF
ROLL ERROR	-.2519 V		
ROLL WHEEL COUNT	0.0 RPM	ACS MODES LOGIC	3 SENSORS ON
YAW ERROR	-.1779 V	ROLL WHEEL DRIVE	OFF
YAW WHEEL COUNT	304.5 RPM	ROLL JETS	ENABLE
YAW WHEEL TEMP	28.52 DEG C		
YAW GYRO BRACKET TEMP	22.5 DEG C	PITCH WHEEL DRIVE	OFF
YAW GYRO MOTOR TACH	0.0 RMP	PITCH JETS	ENABLE
YAW GYRO STATUS	XXX		
ARRAY ERROR	-.2156	YAW WHEEL DRIVE	OFF
ARRAY SHAFT ANGLE (SIN)	181.4 DEG	YAW JETS	ENABLE
ARRAY SHAFT ANGLE (COS)	181.4 DEG	CSA BUS	SAFE
SUN SENSOR TEMP (1)	19.73 DEG C	ORBIT ADJUST	DISARM
SUN SENSOR TEMP (2)	14.82 DEG C	+X ORBIT ADJUST JET	OFF
ACS INV TEMP	29.51 DEG C	-X ORBIT ADJUST JET	OFF
HORIZON SCANNER HEAD A TEMP	20 0 DEG C	+Y ORBIT ADJUST JET	OFF
HEAD A ANGEL	XXX DEG		
HEAD B ANGLE	XXX DEG		
HEAD C ANGLE	XXX DEG		
HEAD D ANGLE	XXX DEG		
SOLAR ARRAY DRIVE	OFF		
ORBITAL SWITCHING STATUS	XXX		

Figure 2-12
ATTITUDE CONTROL SUBSYSTEM display format

01/23 REV 005 RT DATA　　COMMUNICATION SUBSYSTEM

GND GMT 71 023 0511'38
S/C GMT 71 023 0440 25

TWTA 1 ANODE VOLT	XXX V	USB XMTR A PWR	63 DBM
TWTA 1 HELIX + ANODE CURR	XXX AMP	USB XMTR A TEMP	22.7 DEG C
TWTA 1 TEMP	22.0 DEG C		
TWTA 2 ANODE VOLT	XXX V	USB XMTR B PWR	0 0 DBM
TWTA 2 HELIX + ANODE CURR	XXX AMP	USB XMTR B TEMP	22.7 DEG C
TWTA 2 TEMP	22.0 DEG C		
VHF XMTR 1 FWD PWR	3.815 WATT	TWTA 1 PWR MODE	10W
VHF XMTR 1 REV PWR	.0132 WATT	TWTA 2 PWR MODE	OFF
VHF RCVR 1 AGC 1	-84.99 DBM		
VHF RCVR 1 AGC 2	-100.0 DBM		
VHF XMTR 2 FWD PWR	0.0 WATT		
VHF XMTR 2 REV PWR	0.0 WATT		
VHF RCVR 2 AGC 1	0 0 DBM		
VHF RCVR 2 AGC 2	0.0 DBM		
USB CONV A VOLT (+15)	15.0 V		
USB CONV A VOLT (-15)	-15.2 V		
USB CONV A VOLT (+28)	28 7 V		
USB CONV B VOLT (+15)	0.0 V		
USB CONV B VOLT (-15)	0.0 V		
USB CONV B VOLT (+28)	0.0 V		

Figure 2-13
COMMUNICATIONS SUBSYSTEM display format

01/23 REV 005 RT DATA　　DATA HANDLING SUBSYSTEM

GND GMT 71 023 0511 38
S/C GMT 71 023 0440 25

TR 1 VOLT (+9.5)	0.0 V	SCP 2 VOLT (+16)	16 0 V
TR 1 VOLT (-9.5)	0.0 V	SCP 2 VOLT (+9)	9 0 V
TR 1 ENCLOSURE PRESS	30.0 PSIA	SCP 2 VOLT (+5)	5.0 V
TR 1 BASE TEMP	14.77 DEG C	SCP VOLT (-5)	-5.0 V
TR 2 VOLT (+9.5)	0.0 V	SCP 1 TEMP	18 9 DEG C
TR 2 VOLT (-9.5	0.0 V	SCP 2 TEMP	18.9 DEG C
TR 2 ENCLOSURE PRESS	30.0 PSIA		
TR 2 BASE TEMP	14.11 DEG C	TR 1 STATUS	OFF
		TR 2 STATUS	OFF
CLOCK 1 OSC TEMP	47.29 DEG C		
CLOCK 2 OSC TEMP	27.40 DEG C	SIU RCVR 1 SIG PRESENT	NO
		SIU RCVR 2 SIG PRESENT	NO
CALIB 1 VOLT	0 015 V		
CALIB 2 VOLT	0 505 V	LFTA BIT RATE	8 KB
CALIB 3 VOLT	1.707 V		
CALIB 4 VOLT	2 648 V	DDHA STATUS (OSC)	MO 1
CALIB 5 VOLT	3.192 V	DDHA STATUS (HFTU)	HFTU 1
CALIB 6 VOLT	4 126 V	DDHA STATUS (RT/DS)	MC/MC
CALIB 7 VOLT	5.064 V		
		COMMAND STATUS WORD 1	NET 2
ADHA TEMP	29.09 DEG C	COMMAND STATUS WORD 2	GRPA
DDHA 1 BD 3 TEMP	53.20 DEG C	COMMAND STATUS WORD 3	EG 2
DDHA 2 BD 3 TEMP	21 71 DEG C	COMMAND STATUS WORD 4	XXX
LFTA 1 BD 3 TEMP	45 51 DEG C	COMMAND STATUS WORD 5	XXX
LFTA 2 BD 3 TEMP	45 51 DEG C		
		SCP 1 VERIFICATION	XXX
SCP 1 VOLT (+16)	16 2 V	SCP 1 VERIFICATION	XXX
SCP 1 VOLT (+9)	9.1 V	SCP 1 VERIFICATION	XXX
SCP 1 VOLT (+5)	5 0 V	SCP 1 VERIFICATION	XXX
SCP 1 VOLT (-5)	-5.0 V	SCP 1 VERIFICATION	XXX
		SCP 1 VERIFICATION	XXX

Figure 2-14
DATA HANDLING SUBSYSTEM display format

01/23 REV 005 RT DATA THERMAL CONTROL SUBSYSTEM

GND GMT 71 023 0511 38
S/C GMT 71 023 0440 25

ARRAY 1 INBD -X TEMP	28 00 DEG C	PAYLOAD SENSOR TEMP (1)	19.50 DEG C
ARRAY 2 OUTBD+X TEMP	14.00 DEG C	PAYLOAD SENSOR TEMP (2)	19.50 DEG C
		PAYLOAD SENSOR TEMP (3)	21.35 DEG C
PANEL MID THIRD TEMP (+X)	16.00 DEG C	PAYLOAD SENSOR TEMP (4)	21.35 DEG C
PANEL AFT THIRD TEMP (+X)	18.32 DEG C		
PANEL TOP THIRD TEMP (+X)	15.00 DEG C		
PANEL TEMP XX (+X)	17.50 DEG C		
PANEL TEMP XX (+X)	17.50 DEG C		
PANEL MID THIRD TEMP (-Z)	20.00 DEG C		
PANEL AFT THIRD TEMP (-Z)	22.30 DEG C		
PANEL TOP THIRD TEMP (-Z)	20.00 DEG C		
PANEL TEMP XX (-Z)	21.32 DEG C		
PANEL TEMP XX (-Z)	20.35 DEG C		
PANEL MID THIRD TEMP (+Z)	24.00 DEG C		
PANEL TEMP XX (+Z)	22.35 DEG C		
PANEL TEMP XX (+Z)	23.65 DEG C		
PANEL AFT THIRD TEMP (-X)	20.00 DEG C		
PANEL TEMP XX (-X)	19.75 DEG C		
PANEL TEMP XX (-X)	18.35 DEG C		
PANEL TEMP (-Y)	16 45 DEG C		
PANEL TEMP (+Y)	19.35 DEG C		

Figure 2-15
THERMAL CONTROL SUBSYSTEM display format

01/23 REV 005 RT DATA RBV

GND GMT 71 023 0511 38
S/C GMT 71 023 0440 25

LOW VOLT PWR SUPPLY	-200 V	HORIZ ALIGN CURR	OFF
DEFLECTION PWR SUPPLY (A)	10.3 V	VERT ALIGN CURR	OFF
DEFLECTION PWR SUPPLY (B)	-10.1 V	VIDICON FIL CURR	ON
GRID 1 VOLTAGE (P/P)	1 0 V	ANODE VOLT SUPPLY	ON
TARGET VOLTAGE	0.0 V	GRID 2 VOLT SUPPLY	ON
VIDEO OUTPUT	-1.3 V	-24.5 VOLT INPUT	YES
VIDICON CATH CURR	0.0002 AMP	HORIZ SYNC	YES
HORIZ DEFLECTION CURR	1.6 AMP	VERT SYNC	YES
VERT DEFLECTION CURR	0.4 AMP	CAMERA PWR	ON
SHUTTER CURRENT	1.2 AMP	1Hz REPHASING	OFF
FOCUS CURR	0.9 AMP	50 KHz CLOCK INPUT	YES
THERMO ELECT COOLER CURR	1 35 AMP	CAMERA READOUT MODE	ANODE
VIDICON FACEPLATE TEMP	21.5 DEG C	CAMERA PWR	ON
YOKE/FOCUS COIL TEMP	24 0 DEG C	CLOCK	A
ELECTRONICS TEMP	22 5 DEG C	PICTURE CYCLE	CONTINUOUS
LOW VOLT PWR SUPPLY TEMP	23 0 DEG C	EXPOSURE	P3 AUTO/P2-P1
CAMERA CONTROLLER TEMP	21 3 DEG C	DATA TRANSFER MODE	DIRECT
		DYNAMIC BEAM REG	IN

Figure 2-16
RETURN BEAM VIDICON display format

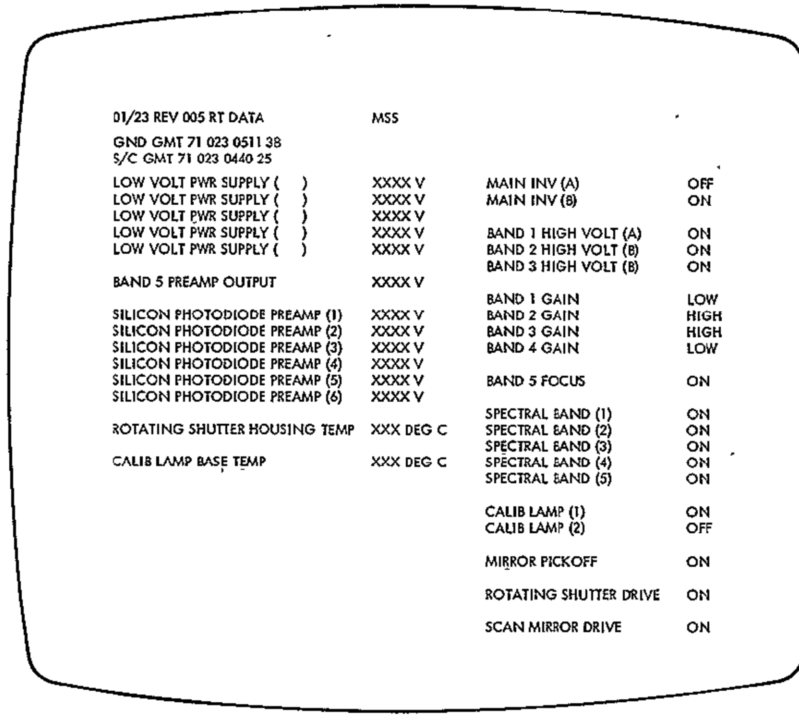


Figure 2-17

MULTISPECTRAL SCANNER display format

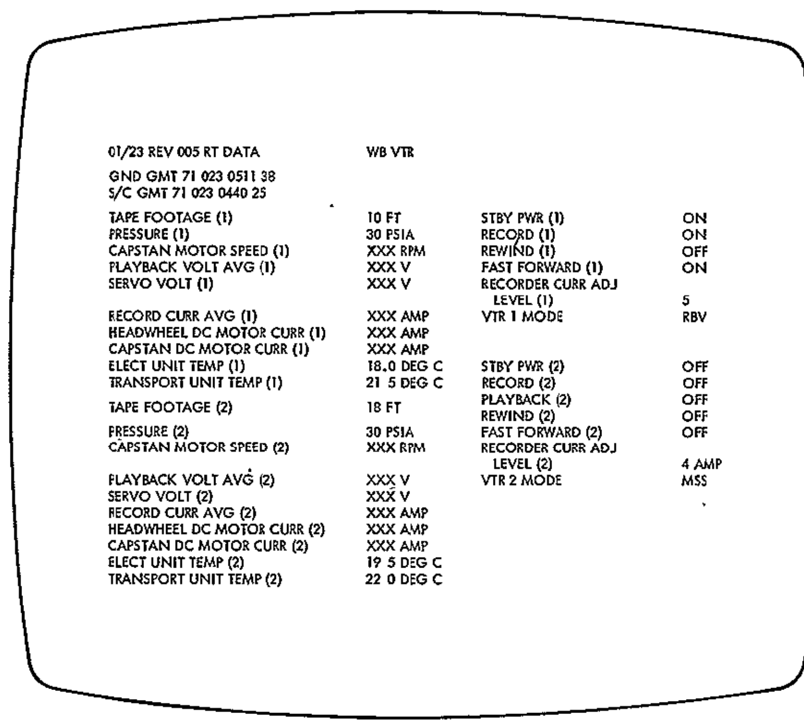


Figure 2-18

WIDEBAND VIDEO TAPE RECORDER display format

2.5 COMMUNICATIONS AND DATA DISTRIBUTION

The communications and data distribution functions are accomplished by utilizing a number of resources: NASCOM communication facilities for high data rate activities, U.S. mails for delayed data tape collection, and telephone circuits for coordination and callup capability to remote stations.

2.5.1 Information Flow

The OCC serves as the central point of control for all ERTS activities for both the continental United States and worldwide operation. Figure 2-19 provides an overview of the generic information flow required during launch, emergency, and routine operations. The information flow to the OCC falls into three major categories: real-time, near real-time, and delayed.

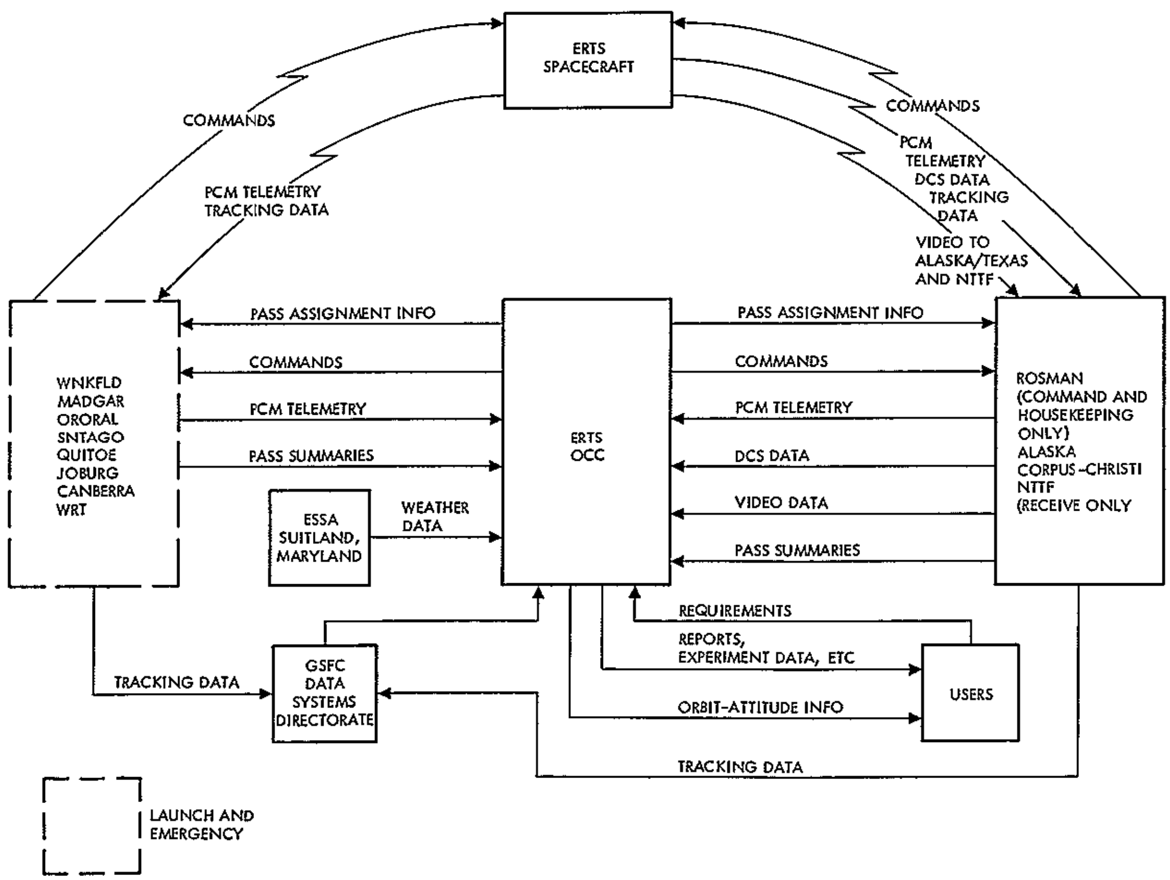


Figure 2-19
OCC DATA INTERFACE block diagram

Observatory commands, PCM telemetry, and tracking data constitute the primary real-time information. The tracking data is transmitted to GSFC Data Systems Directorate for determination of the ephemeris which is then sent to the OCC for operations scheduling purposes. Spacecraft commands and PCM telemetry require real-time transmission links between the OCC, the remote sites, and the observatory. Near-real-time data is defined as that operational data which is required at the OCC within one observatory pass period. Pass assignment, pass summary, and DCS data fall in this category. DCS data constitutes a primary near-real requirement and must also have special handling considerations due to its unique information structure.

Delayed data is that which is required in a timely manner but not restricted to a pass period time element. This includes weather data, ephemeris, user requests and information, MSS and RBV video tapes as well as DCS. Delayed data is transmitted via the U.S. mail, teletype, telephone, or courier.

Figures 2-20 through 2-25 provide a graphic representation of the flow of data from the observatory to the OCC. Definitions of abbreviations are given in Table 2-8.

For chart interpretation, start with the left-hand column which defines the data of interest and proceed to the right via the ground station in question. Any point (●) on a given line of data flow indicates some operation on the data; all other points unmarked have no bearing on that line. A number (e.g., 9K) is used in lieu of (●) to indicate the speed of the data at that point.

Note also the following in regard to MSS and RBV data. The observatory can produce four versions of these; MSS-RT, MSS-PB, RBV-RT and RBV-PB. It can transmit any two of these over S-band carriers No. 2 and No. 3. However, there is currently a limitation at the ground stations in that they can handle only one set of MSS and one set of RBV. This is because they have only one set of recording/demux equipment for each. The only way to get <u>any two</u> of the four versions is to duplicate their recording/demux equipment.

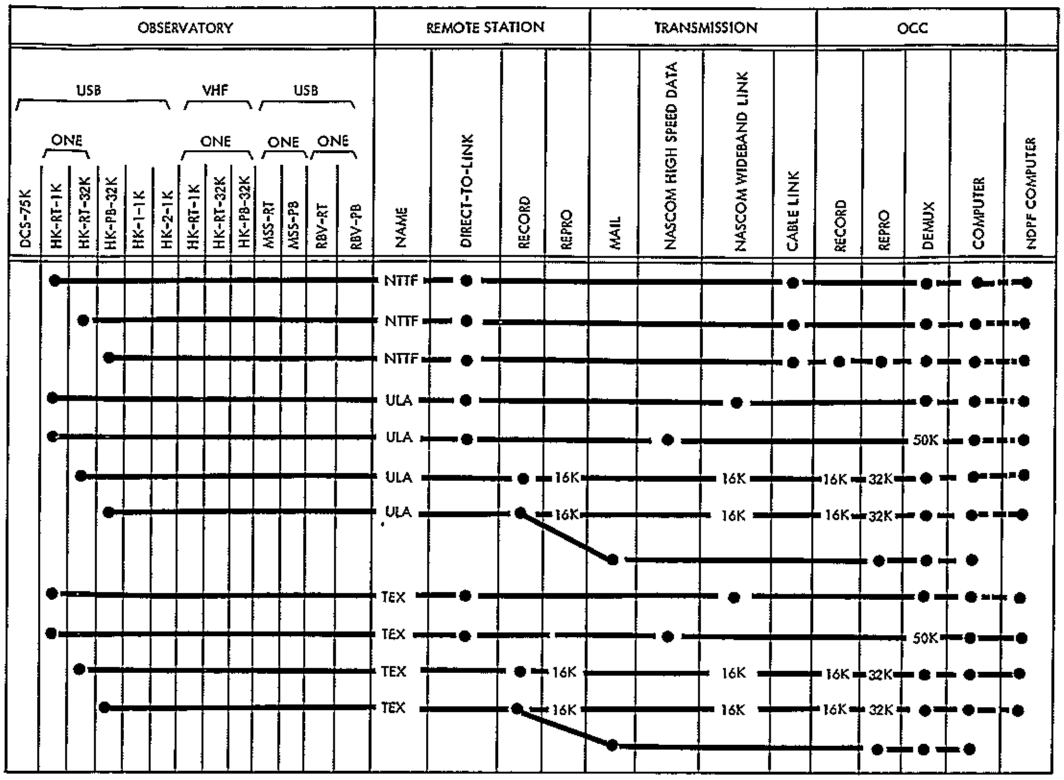


Figure 2-20

PRIME STATION HOUSEKEEPING - ERTS data flow

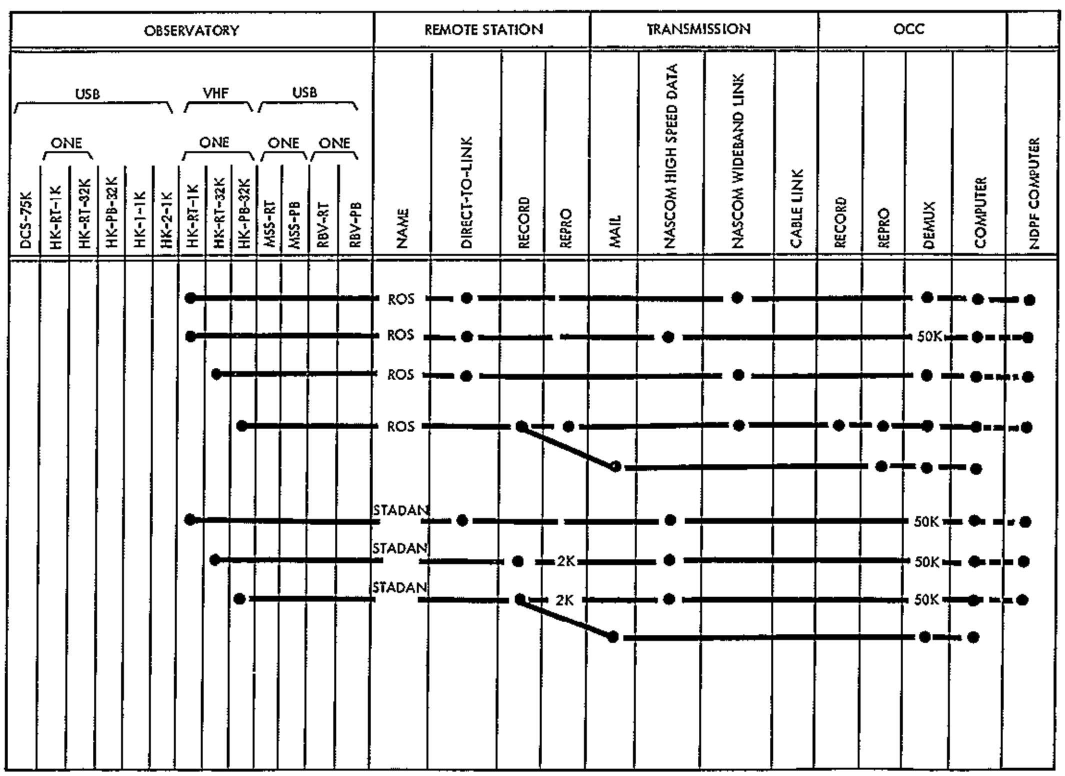


Figure 2-21

VHF HOUSEKEEPING - ERTS data flow

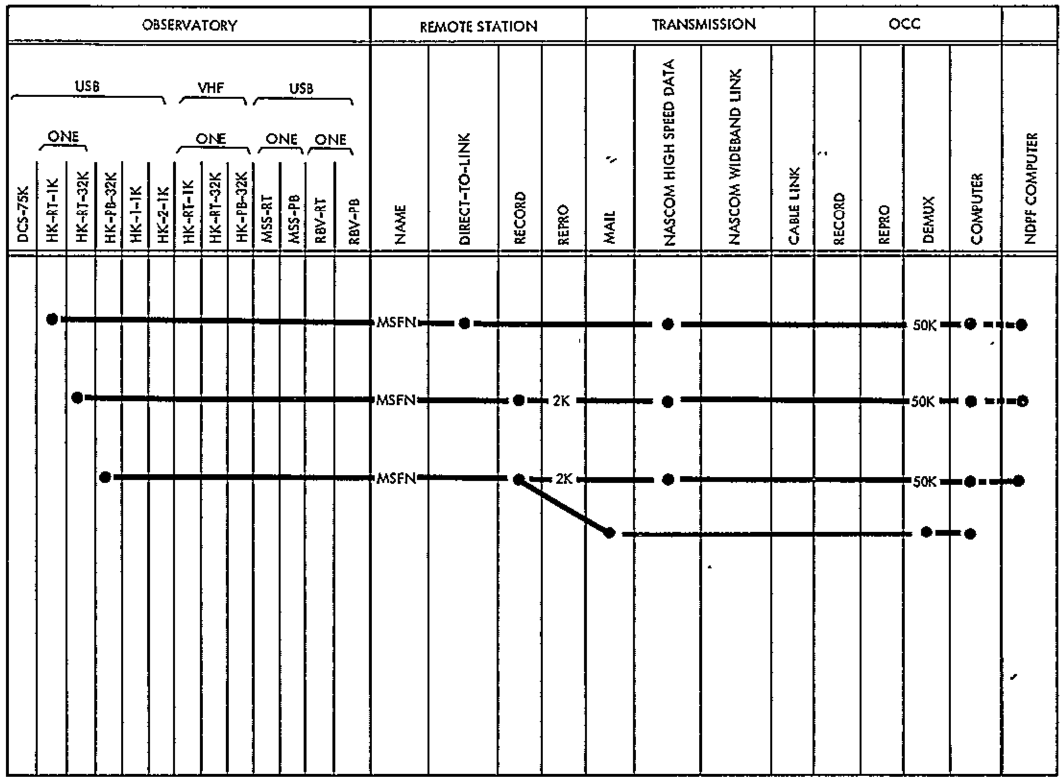


Figure 2-22

UNIFIED S-BAND HOUSEKEEPING - ERTS data flow

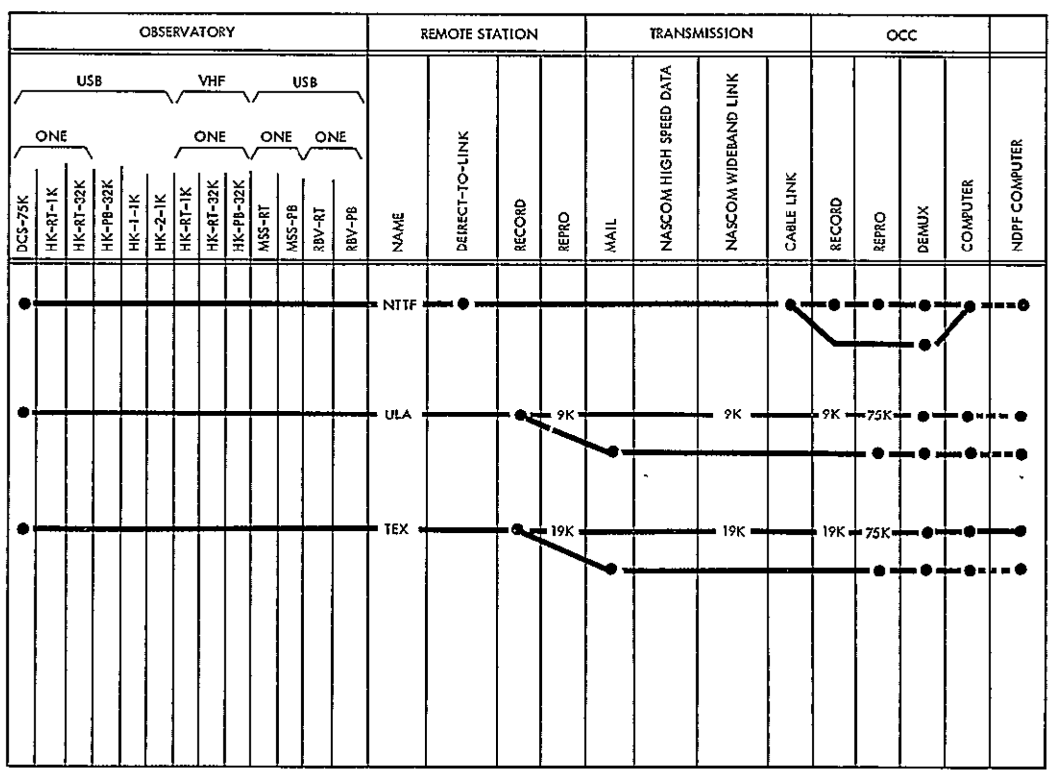


Figure 2-23

DATA COLLECTION SYSTEM - ERTS data flow

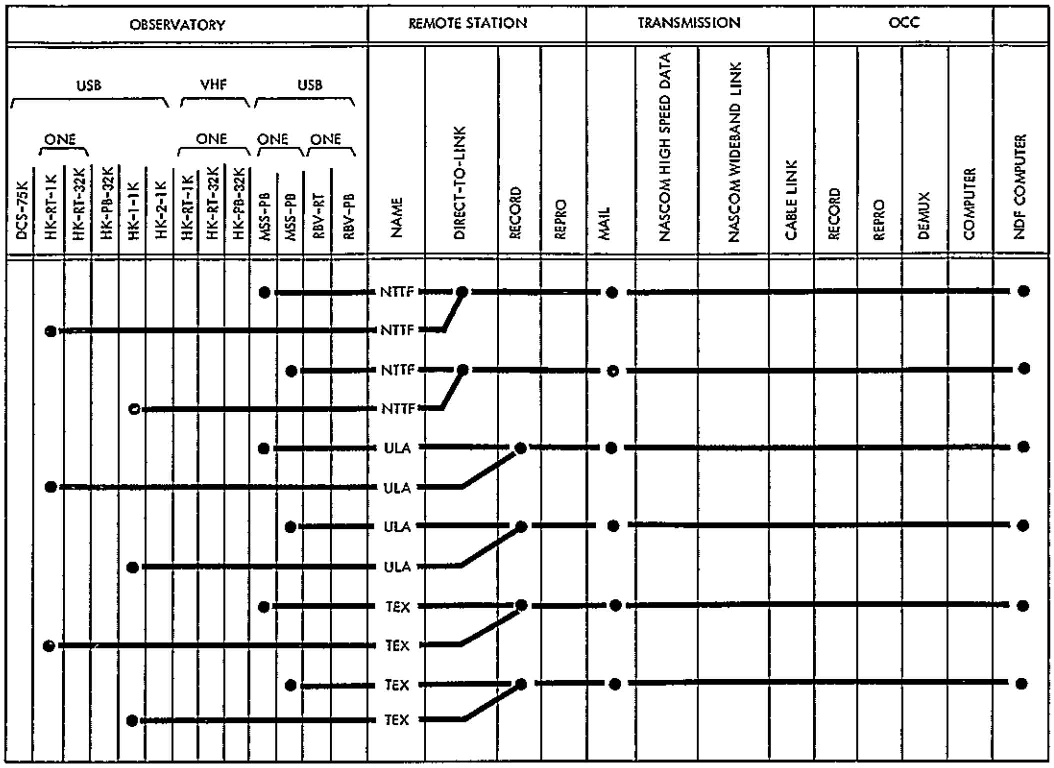


Figure 2-24

MULTISPECTRAL SCANNER - ERTS data flow

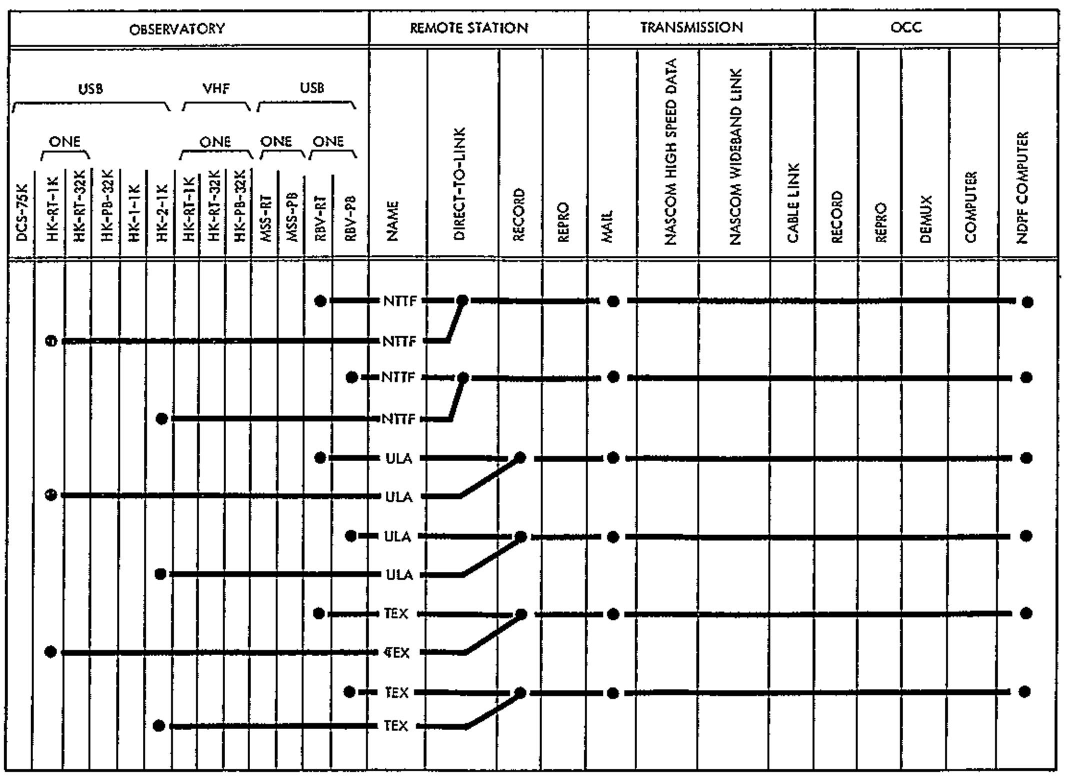


Figure 2-25

RETURN BEAM VIDICON - ERTS data flow

Table 2-8. ERTS Data Flow Definitions

DCS-75K:	DCS IF at 75 khz center frequency and bandwidth of 125 khz
HK-RT-1K:	Housekeeping real-time at 1 kbit/sec (normal)
HK-RT-32K:	Housekeeping real-time at 32 kbits/sec (accelerated)
HK-PB-32K:	Housekeeping from the narrowband PCM recorders at 32 kbits/sec
HK-1-1K:	Housekeeping from video recorder used for MSS at 1 kbit/sec
HK-2-1K:	Housekeeping from video recorder used for RBV at 1 kbit/sec
MSS-RT:	MSS PCM real-time
MSS-PB:	MSS PCM from video recorder
RBV-RT:	RBV video real-time
RBV-PB:	RBV video from video recorder
Direct-to-link:	Ground station sends data over the link immediately on receipt
Record:	Magnetic tape recording
Repro:	Magnetic tape reproduction
NASCOM wideband link:	Transmission over a wideband data link
NASCOM HSD:	Transmission over the high-speed data system using the Univac 494 switching computer. Data from the switching computer to the OCC comes at A50 kbits/sec rate in blocks (bursts) of 600 bits.
Cable link:	Direct cable between NTTF and GDHS. (may be a microwave link)
Demux:	Used to define any processing of raw data into computer format (e g., the PCM decommutator)
ONE:	Indicates only one of the functions named can be transmitted through the system.

NOTE: Any operations on the data which are not part of the actual data flow are not shown (e. g., recording of data as backup against link failure).

Figure 2-26 illustrates the utilization of existing and new NASCOM facilities to support ERTS operations between the remote sites and the OCC at GSFC. Voice, teletype, high-speed and wideband data link services from the existing NASCOM facilities are required. In addition, a 20 kHz wideband link is required from Texas to provide a DCS data link. Also, broadband video and PCM links to NTTF are required to provide real-time transmission of imagery data.

The NTTF video link provides the only real-time imagery link to the OCC for real-time monitoring, analysis, and control of the RBV and MSS payloads.

Figure 2-27 shows the communications routing within GSFC and the local area supporting agencies. This figure is not all-inclusive with

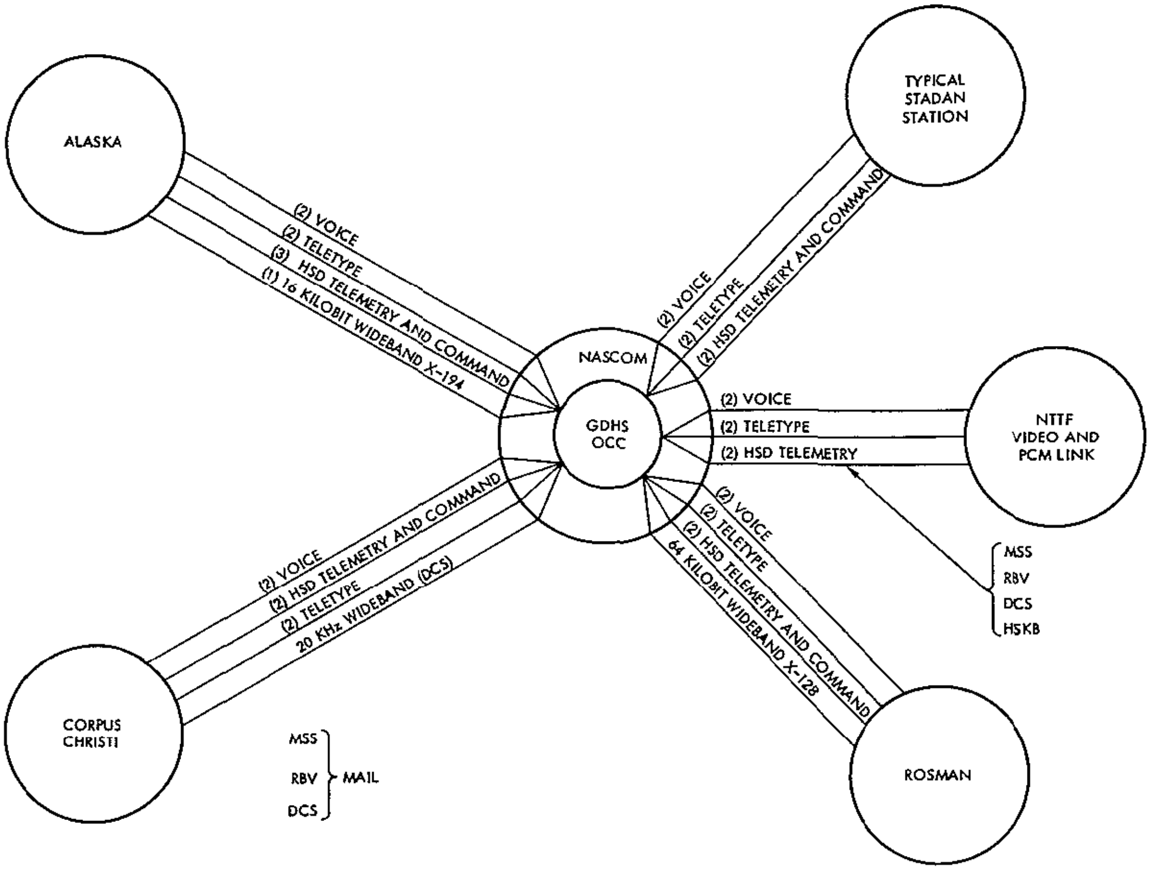


Figure 2-26
ERTS GROUND COMMUNICATIONS NETWORK

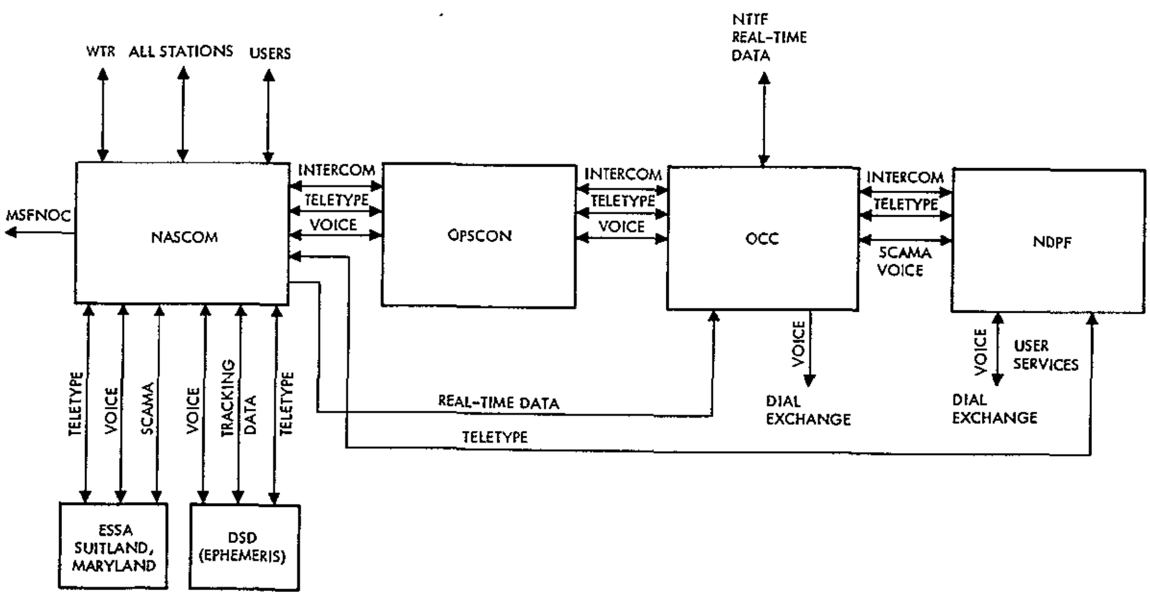


Figure 2-27
ERTS GSFC COMMUNICATIONS NETWORK

respect to GSFC local function usage. It illustrates the primary communications and data interfaces required for ERTS operation. The pertinent aspect is the NASCOM routing of data and communications between the OCC, OPSCON, MSFNOC, mission control, remote sites, and other agencies.

2.5.2 Synoptic Description

The communications and data distribution system utilizes existing NASCOM, remote site, and NTTF capabilities and also integrates NASA planned improvements at these facilities. Figure 2-28 presents an overview of the OCC, NASCOM, and assigned remote sites equipment necessary to support ERTS. The equipment is grouped by type: voice, teletype, high-speed data, wideband data, OCC distribution, and OCC recording equipment.

The voice links consist of SCAMA conference, SCAMA auxiliary patchfield, GDHS intercom with SCAMA circuit inter-tie, and dial exchange circuits. The voice links provide coordination and control capability for all phases of ERTS operations. Figure 2-29 illustrates the type of voice circuits required and shows direct link circuits between NDPF, OCC, OPSCON, MSFNOC, WTR, mission control, and remote sites. As can be seen in Figure 2-28, access to SCAMA conference circuits with signaling capability to remote sites through connected circuits to prime sites with signaling, and through connected circuits for GSFC local use without signaling is provided by interconnection with the GDHS intercom equipment on a selective circuit basis. Figure 2-29 illustrates the OCC and NDPF equipment stations which require interconnection with SCAMA circuits. The dial exchange voice circuits provide additional local usage and backup for the primary voice circuits.

Teletype links provide transmission of schedule data, pass summary data, weather data, user data, technical data, and serve as a backup mode for the high-speed data and wideband links. The terminals are automatic send-receive with auxiliary reperforator capability.

NASCOM high-speed data links provide the primary real-time observatory data communications. Spacecraft commands and spacecraft housekeeping telemetry data are transmitted between the remote sites and the OCC over these links.

PRECEDING PAGE BLANK NOT FILMED.

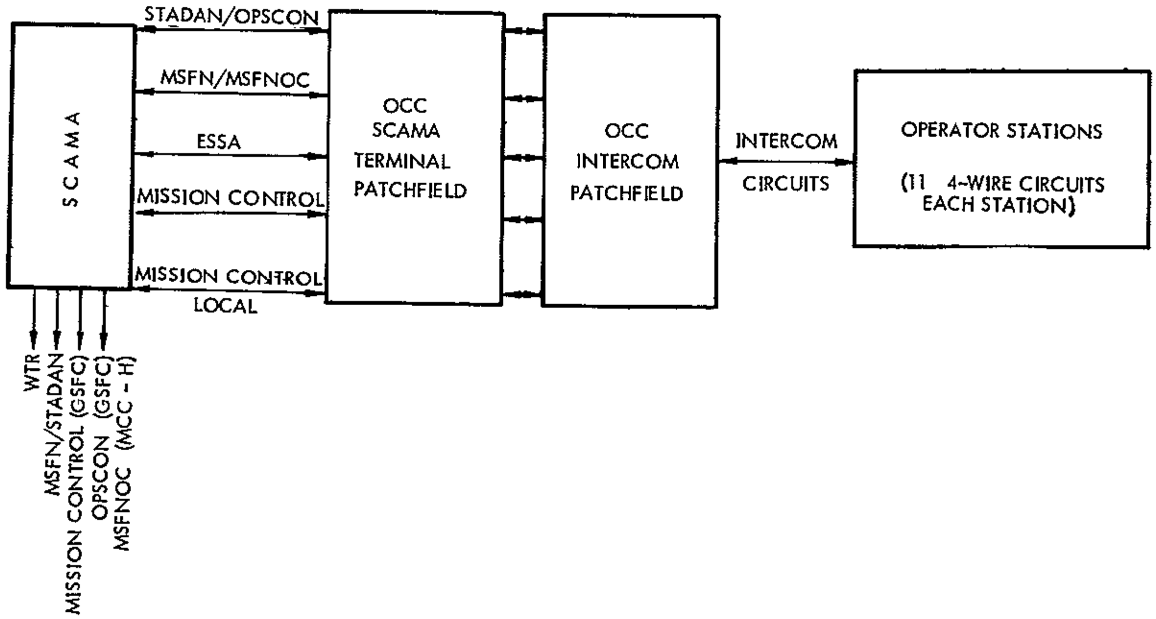


Figure 2-29
VOICE CIRCUITS

Command data is generated in the OCC computer. This data includes parity, error coding if applicable, and NASCOM 600-bit data block structure. On operator execution the command data block is transferred in bit-parallel form to the OCC data interface buffer. The data interface buffer receives the parallel data at the computer data rate, converts the data to a serial bit-stream, and transmits the serial data to the WECO 303C 50 kbits/sec data modem in the OCC communication terminal rack. The modem transmits the data to the high-speed data switching center which terminates the line with another WECO 303C modem. This modem transmits the 600 bits of data to a modified communications line terminal capable of handling 50 kbits/sec, 600-bit block data in full duplex mode. The switching computer then transfers the data via a standard communications line terminal to the WECO 205B modems which presently operate at 2.4 kbits/sec and are planned for future operation at 4.8 kbits/sec. The WECO 205B modem links provide access to the remote sites. Additional high speed data links exist for worldwide and CONUS operation at similar or higher transmission rates.

The command high speed data link is full duplex, and command validation messages from the remote sites travel the inverse route. The data interface buffer receives the serial data message, converts it to parallel

form and transfers the data to the OCC computer for the necessary data operations. Voice and teletype links serve as a backup for contingency conditions. The command link also provides a backup link for the telemetry data with direct access to the OCC computer.

During normal operations the command and telemetry high speed data links operate as separate entities. The telemetry data is received at the switching computer center from the remote sites over links identical to the command links. The data is then transferred in 600-bit blocks to the telemetry modified communications line terminal and WECO 303C modem. This data is received in the OCC data interface buffer via the receiving WECO 303C modem. The data interface buffer receives the 50 kbits/sec, 600-bit block data, strips off all overhead data (NASCOM header and fill data), formats the telemetry data into the spacecraft mainframe form, and strobes the data into the data handling equipment at 1 or 4 kbits/sec. This provides a continuous smooth flow of data to the data handling equipment and allows for synchronization with the spacecraft mainframe at all times. To accomplish the NASCOM block structure demultiplexer in the NASCOM bloack structure demultiplex in the data interface buffer, it will be necessary for both MSFN and STADAN stations to identify data and block fill data with data and fill descriptors.

Wideband data links from Alaska and Texas provide OCC acquisition of DCS data in near-real-time. These links also provide a backup mode for transmission of spacecraft telemetry. Wideband links from NTTF provide real-time acquisition of HK-1 kbits/sec (normal), HK-32 kbits/sec (accelerated), DCS data, RBV and MSS video data. Also, the existing wideband data link from ROSMAN can provide emergency 1 and 32 kbits/sec HK-real-time data. (ROSMAN is normally utilized as a command uplink station and NTTF serves as the local receiving site).

The input desired at the OCC for DCS processing is the 100 kHz IF spectrum from 25 to 125 kHz containing periodic and independent phase-shift-keyed signals at spectral locations corresponding to their individual carrier frequencies, modified by the doppler components.

Receiving the IF from NTTF can be by hard line, since it is close to the GDHS. From Alaska to GSFC the NASCOM wideband link has the

capability to transmit analog up to 23 kHz. The IF would therefore have to be handled by means of a 1/8 speed playback, providing a received band between the limits of 3.1 and 15.6 kHz. A 10-minute pass will then require 80 minutes on the data link to be relayed to the GDHS. The NASCOM wideband link does not exist between Texas and GSFC. The proposed solution is a tariffed line of 300 Hz to 20 kHz width. The same technique as for Alaska would then be used.

However, in projecting into the future, it is obvious that these solutions will not hold for receiving the IF from overseas stations. For overseas stations there will be no alternative (other than mail) but to receive the IF to PCM at the receiving station and transmit this via the NASCOM high speed data links.

The Texas, Alaska, and Rosman wideband links communicate with the OCC via NASCOM's wideband data technical control facility. Transmission from this facility to the OCC will be over 135-ohm, 1VP-P coaxial cable lines. These lines terminate in the OCC data distribution unit where they are impedance matched, line isolated via line drive amplifiers, and routed to the appropriate equipments via a signal select switch unit and patch panel.

The NTTF wideband data will arrive at the OCC over 135-ohm coaxial cables and will terminate in the data distribution unit and be handled in the same manner as the above data links. Table 2-9 tabulates the data link utilization showing data type, transmission method, and data rates for both high speed data and wideband links.

2.5.3 OCC Communications and Data Distribution Equipment

The OCC communications and data distribution equipment falls into two distinct categories: 1) equipment to be provided by NASCOM, defined as the communications segment, including operational (SCAMA) voice, teletype, intercom, dial exchange, and high-speed data modems; and 2) the data distribution segment furnished by TRW.

2.5.3.1 Communications Segment Equipment

The communications segment includes NASCOM voice and teletype high-speed data modems, dial exchange and intercom equipment not only

for the OCC but for all of the GDHS and for launch as well as for the operational phase. This equipment was listed in Figure 2-19.

Intercom. The intercom subsegment provides routing for all voice communications in the GDHS except for dial exchange circuitry. SCAMA conference and auxiliary patchfield circuits interface with the OCC via the intercom. Figure 2-30 illustrates the intercom and SCAMA interface.

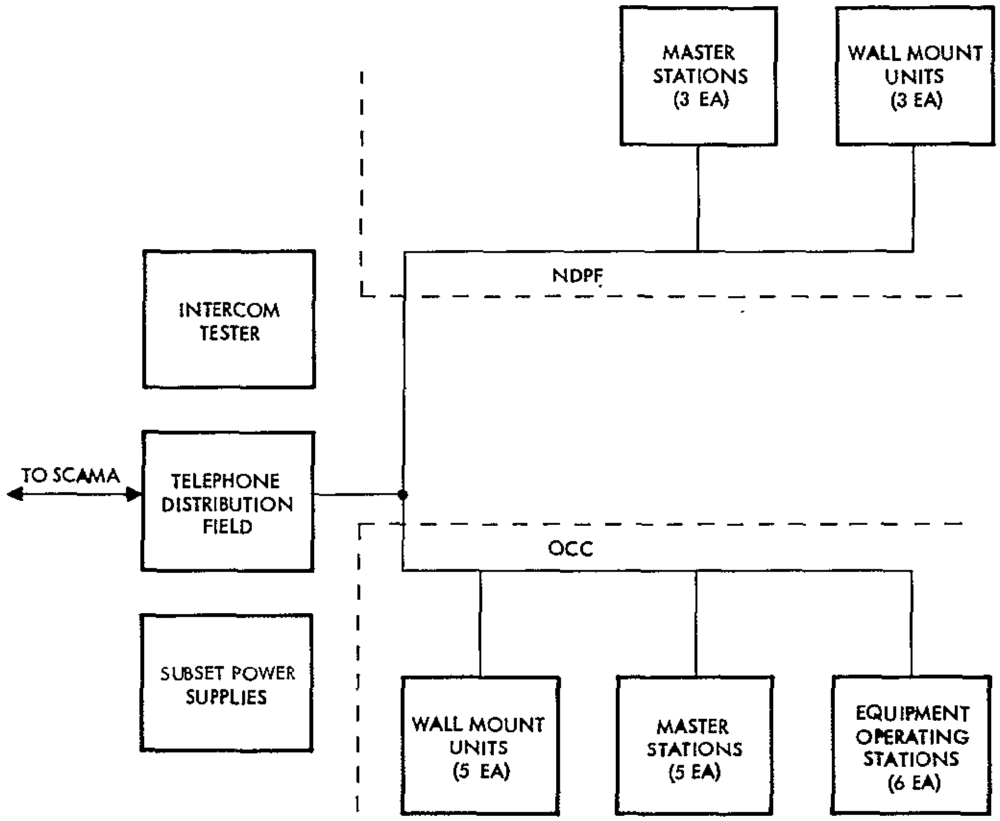


Figure 2-30
TELECOM block diagram

The voice patch panels and multiple cable runs provide a means of selectively routing voice circuits to the appropriate operating stations and positions. For instance, during normal operation NDPF does not require access to SCAMA conference circuits and therefore would not be patched in. In the backup or contingency mode, the NDPF unified display consoles and SCAMA access is required. This is accommodated by proper patching. Figure 2-30 shows the circuits and functional positions using each

circuit for normal operation. In addition to these positions, wall mounted units will be located in the service areas for coordination. These units will function primarily as paging for service.

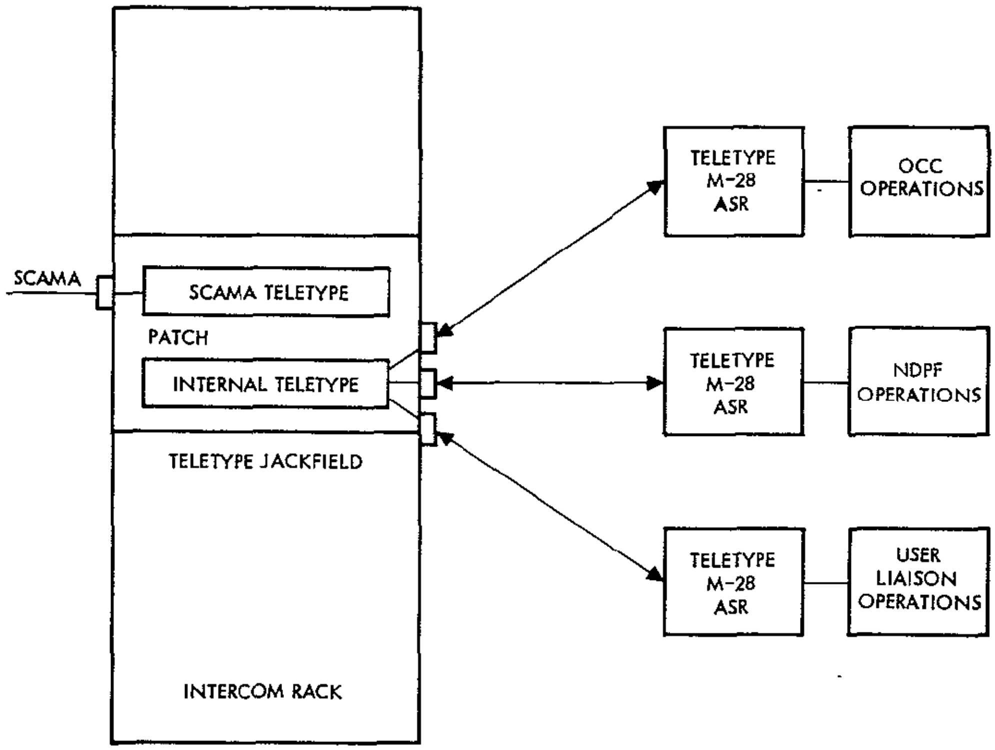


Figure 2-31
TELETYPE block diagram

Teletype. The teletype subsequent requires a minimum of three full duplex circuits between the GDHS and NASCOM switching center. Switching access to remote sites, supporting agencies, and user agencies is required. One circuit is required for support of OCC operations, the other two are for NDPF use. Figure 2-31 illustrates the interface and use of the teletype circuits. The patch panel provides flexibility in routing and circuit test access. The teletype terminals are Teletype Corporation Model 28 automatic send-receive with page printer and auxiliary reperforation.

2.5.3.2 Configuration

The communications equipment segment of the communications and data distribution subsystem in the GDHS provides signal interface, signal

conditioning, signal routing, signal switching, and terminal equipment for operational voice, intercom voice, and teletype communications.

This segment consists of communication distribution rack, intercom equipment, teletype terminals, high-speed data modem rack, and dial exchange receiver transmitter sets.

- Communication Distribution Rack. The communication distribution rack contains eight units. SCAMA voice patch panel, intercom patch panel, operator intercom station, intercom testor, two intercom power supplies, teletype patch panel, and dial telecom unit.

- Intercom Equipment. The intercom equipment permits operators of the GDHS to communicate with one another from various stations and with SCAMA via headset communication. Further, paging capability shall be provided for GDHS.

- Teletype Terminals. The teletype terminals will have the capability of automatic send-receive with page printer and auxiliary reperforator.

- High-Speed Data Modem Rack. The high-speed data modem rack will contain three WECO Model 303 data modems, two for on-line command and telemetry communications, and the third used as a spare.

- Dial Exchange Telephones. Four public dial exchange circuits will be required for local telephone exchange calls and operations support communications.

- Dial Telecom Unit. One dial telecom unit with ringdown capability to the NASCOM circuit repair operators station will be required.

The communications equipment will operate as a separate entity, independent of any other communication system in the facility with the exception of the dial exchange system. The equipment will operate within the voice frequency range (300 to 3000 Hz) on each audio net or data circuit.

In addition, the intercom equipment will operate as a separate entity, independent of any other communication system in the facility. The equipment will operate within the voice frequency range (300 to 3000 Hz) on each of 10 four-wire audio channels with, as a minimum, an individual solid-state amplifier pair, transmit and receive, at each station.

2.5.3.3 Interfaces

SCAMA Patch Panel. The SCAMA patch panel (Figure 2-32) provides interface terminations for all SCAMA lines on terminal board 1 as illustrated in Figure 2-33. Terminal board 2 provides the strapping points for patching the SCAMA lines into the internal intercom system. All circuits are terminated by 620 ±5 percent ohm loads when circuits are not in use.

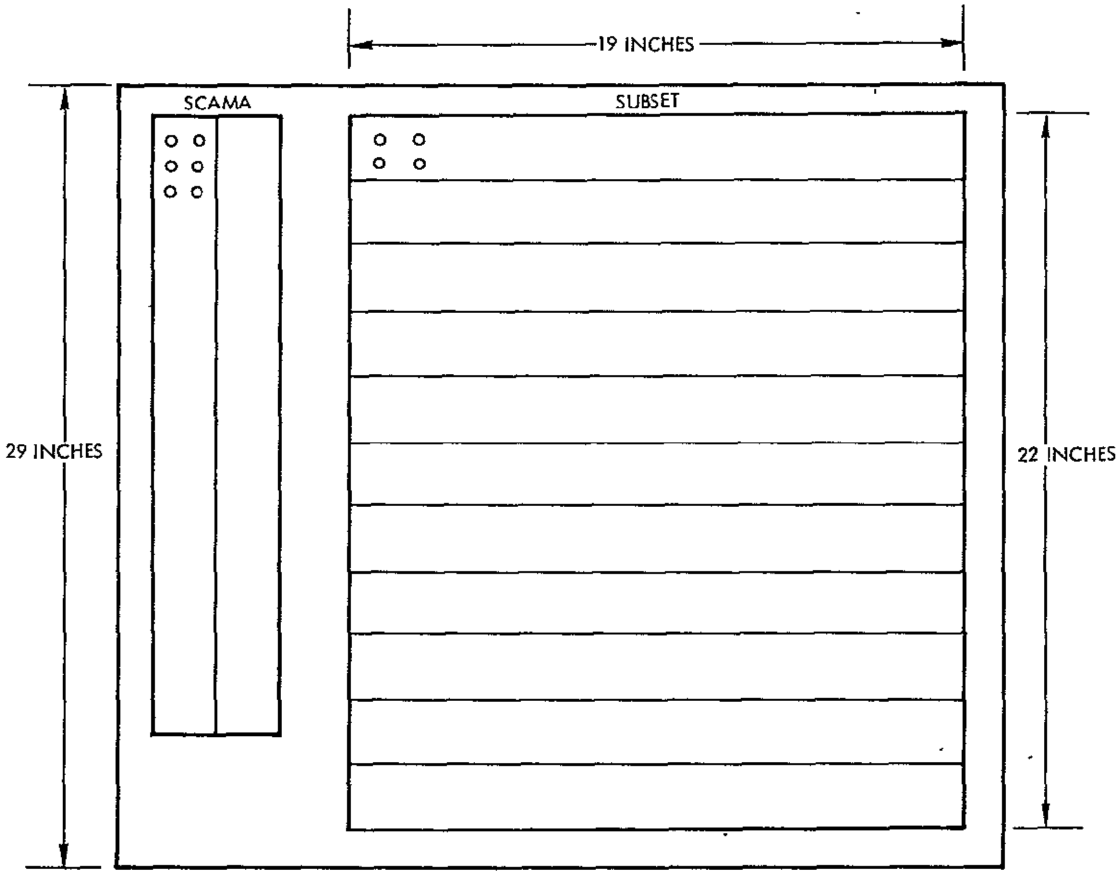


Figure 2-32
SCAMA PATCH PANEL

Intercom Patch Panel. The intercom patch panel provides jacks for checking each pair (transmit or receive) of intercom lines wired through the communication rack. The intercom jack field is connected to the SCAMA jack field via Terminal board 1 to 2, Terminal board 3 to 4, etc., as illustrated in Figure 2-33.

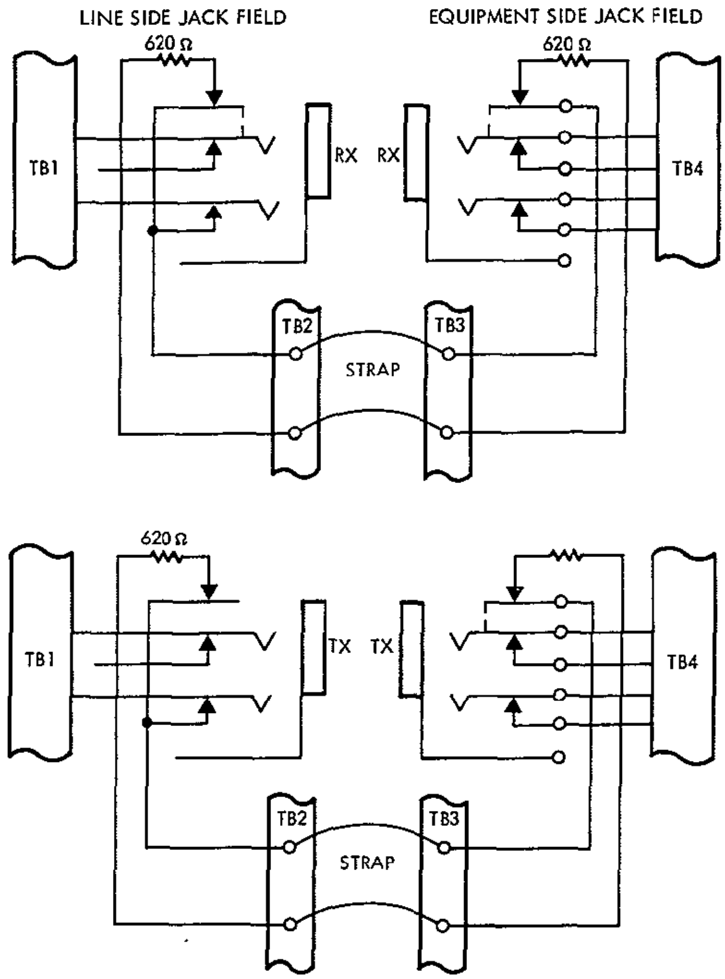


Figure 2-33

TYPICAL CHANNEL CONNECTION outside switch (SCAMA) to inside line

Teletype Patch Panel. The teletype patch panel provides input-output patch routing for five full duplex teletype circuits. All circuits will be terminated when not in use.

Operator Intercom Station. The operator intercom station is a rack-mounted unit which permits the operator to transmit and receive on any one of 10 channels selected by push-button switches. The operator is able to monitor his transmitted signal in the headset receiver.

Intercom Tester. The intercom tester contains a test tone generator, VU meter, and access jacks for connecting various test signals into the system with patch cords.

Subset Power Supplies. The intercom power supplies interface with the intercom equipment and provide all power required. The intercom equipment operates from a central 28 vdc power source. One supply is for on-line use; the second supply provides backup.

2.5.4 Data Distribution Segment

Data distribution for ERTS will be discussed in three sections. The first section will discuss data distribution from ERTS dedicated ground sites to GSFC. The second section will discuss signal switch service within GSFC to the ERTS-OCC and finally, a third section will describe data distribution within the OCC.

2.5.4.1 Ground Stations to GSFC

NASCOM GSFC to Texas Circuits. Present GSFC to Texas circuits are identified in the following table:

Circuit Type	Number	Capabilities
Teletype	2	60 words/min, full duplex
Voice/data	6	0.6, 1.2, 2.4, 4.8 bits/sec or 3 khz (nominal) analog. Full duplex operation.

Data terminal equipment consists of Model 28 teleprinters for teletype circuits and WECO 205B modems for voice/data circuits. All circuits have full duplex capabilities.

Observatory telemetry data will be routed to GSFC in real-time or by a post-pass tape recorder playback. Telemetry data will be routed on a voice/data circuit and consequently only 1 kbit/sec telemetry may be sent in real-time. The spacecraft wideband sensor data will be recorded at the Texas telemetry/computer site and mailed to GSFC.

DCS data (25 to 125 kHz) will be recorded at the Texas telemetry/computer site. Tentative plans are to install a 20 kHz bandwidth circuit to Texas and playback DCS data at slow speed over this channel. Alternate techniques will be to install a 137.5 kHz bandwidth circuit for DCS real-time service, to install a DCS signal recovery system on site, or to mail DCS tapes to the OCC.

NASCOM GSFC to Alaska Circuits. Present GSFC to Alaska circuits are identified in the following table:

Circuit Type	Number	Capabilities
Teletype	2	100 words/min, full duplex
Voice/Data	6	0.6, 1.2, 2.4, 4.8 bits/sec or 3 kHz (nominal) analog. Full duplex operation.
X-144 Wideband	1	2 to 48 kHz circuits (each way) six channelization modes per circuit

Data terminal equipment consists of Model 28 teleprinters for teletype circuits and WECO 205B modems for voice/data circuits. The X-144 modem is a specially built item.

Circuit assignments for ERTS data and command communications are as follows:

Data	Transmission Techniques
1 kbit/sec telemetry	Via voice/data at 2.4 kbits/sec or via X-144 at 1 kbit/sec
32 kbits/sec telemetry	Via voice/data at 2.4 or 4.8 kbits/sec or via X-144 at 16 bits/sec split phase or 32 kbits/sec NRZ
Sensor data	Mail
Commands	To Alaska via voice/data. Teletype circuits may be used for backup.
DCS data	Slow playback (1/8 of record speed) via the X-144 23 kHz analog channels.

Alternative techniques would be to expand the X-144 link capability to 48 kHz of full analog to increase the DCS tape recorder slow down ratio from 1/8 to 1/4 of record speed, or to install a DCS signal recovery system onsite.

NASCOM GSFC to Rosman Circuits. The Rosman STADAN station will serve primarily as a command station. Since the NTTF is restricted to a receive-only status, Rosman will perform uplink command transmissions for the NTTF. In a backup mode Rosman can receive observatory 1 and 32 kbits/sec telemetry VHF downlink transmissions. GSFC/Rosman circuits available for ERTS usage are identified below:

Circuit Type	Number	Capabilities
Teletype	3	100 words/min, full duplex
Voice/data	4	0.6, 1.2, 2.4, 4.8 kbits/sec or 3 kHz (nominal) voice. Full duplex
X-128 wideband	1	1 MHz; multichannel
15 kHz wideband	2	Two simplex circuits. Previously used for OGO command transmission.

Command transmission from GSFC to Rosman will be via a voice/data circuit or via the 15 kHz wideband circuit and command verification may be returned to GSFC a voice/data or 15 kHz wideband circuit. If required, Rosman can route telemetry data to GSFC via a 2.4/4.8 kbits/sec voice/data circuit or via a 128 kHz digital channel of the X-128 link. This channel is capable of carrying either 1 or 32 kbits/sec spacecraft telemetry. Rosman is not presently able to receive the ERTS S-band downlinks.

NASCOM NTTF to ERTS-OCC Circuits. Data received by the NTTF will be routed directly to the OCC data distribution segment by the following circuits:

Circuit Type	Number	Use
Coaxial cable	2	PB telemetry and real-time telemetry. Each cable capable of operation up to 32 kbits/sec.
Coaxial cable	1	DCS data. Circuit bandpass of 25 Hz to 125 kHz required.
Coaxial cable or microwave	2	MSS data and RBV data. One circuit each.

Primary Switching Center. Nearly all NASCOM teletype and high-speed data lines are hubbed on the Univac 494 switching center system at GSFC. The 494 SC system is a real time processor specifically designed for automatic switching of teletype and digital data messages.

Incoming high-speed data and voice/data is reconverted to a PCM wavetrain by WECO 205B modems. Data recognized by the switching computer as destined for the ERTS OCC is switched to WECO 303C modems for relaying to the OCC. The WECO 303C modems transmit data to the OCC in 50 kbit/sec, 600-word blocks. ERTS teletype data is reconstructed and then switched by the Univac 494 to the OCC.

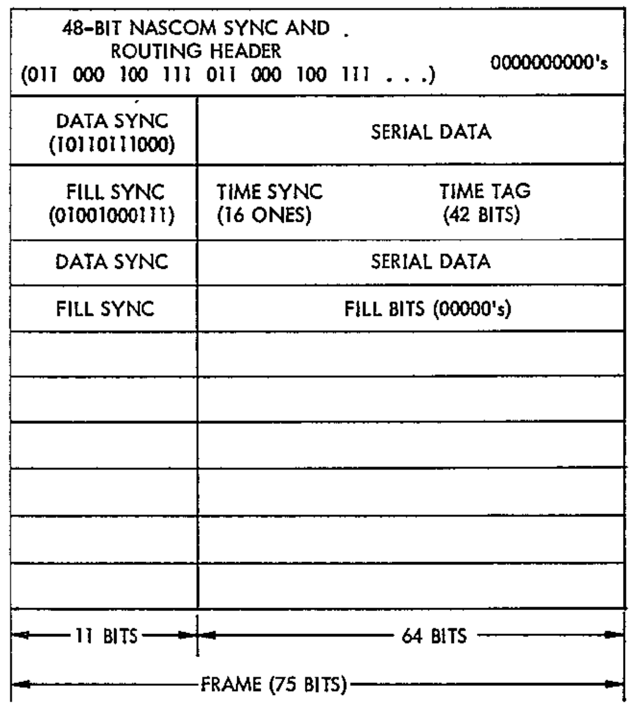
Wideband Technical Control Center. The wideband technical control center serves as the interface between the OCC and the commercial carrier wideband links to Alaska, Rosman, and the MCC-H. ERTS data present on these links consists of demodulated PCM and baseband analog (DCS data) that is routed to the OCC data distribution unit via coaxial cables.

NASCOM Data Formats. Presently, differences exist between data formats transmitted by MSFN and STADAN stations. For data handling efficiency within the ERTS-OCC, a small modification will be made to the MSFN data format when ERTS data is being transmitted to the OCC. This modification consists of adding a leading 11-bit data sync word before the data bits, and an 11-bit fill sync word before the trailing zeros in an MSFN format. The fill and data sync words will be identical to those within the STADAN format. The required format is illustrated in Figure 2-34.

If, at a later date, STADAN stations change to a standard MSFN format, only a minor modification will be required to the data interface buffer in the ERTS-OCC.

2.5.4.2 Data Distribution Within the OCC

Information and data flows bidirectionally between the OCC and NDPF. This flow occurs through the services of the central ADPE, the unified display system, and manual transfer of materials (hard-copy, tapes, etc.). During normal operations communications data entering the



STANDARD NASCOM BLOCK EQUALS 600 BITS OR A MULTIPLE OF 600 BITS.
BIT SPACES IN EXCESS OF 48 IN THE HEADER FRAME WILL BE ZEROS.

Figure 2-34
TYPICAL NASCOM DATA BLOCK

OCC, with the exception of the RBV, is processed through the OCC computer and delivered to the NDPF in suitable form. Real-time RBV data from NTTF is received in the OCC, amplified and routed directly to the NDPF for video processing which makes the imagery available via the unified display system.

Overview of OCC Data Interface

All data traffic, incoming and outgoing, interfaces with the OCC data distribution unit. This unit contains five functional elements that perform switching, buffering, formatting, format stripping, time code generation, and data reconstitution as appropriately required by incoming and outgoing data. The data distribution unit interfaces with the automatic data processing equipment and the stored program PCM decommutator. Several functions of the ADPE, during prime mode operation, consist of processing housekeeping telemetry, processing raw PCM from the DCS

demodulator, and generation, verification, and validation of command data. During housekeeping PCM telemetry processing the stored program PCM decommutator routes data from the data distribution unit to the ADPE. The PCM decommutator receives PCM data from the data distribution unit formatted as a replica of the data stream that was originally transmitted from the spacecraft. The PCM decommutator strips out word/words from the spacecraft main frame and presents them in parallel to the ADPE. Alternately, the PCM decommutator can route decommutated PCM to recorders for storage and display.

Data Distribution Modes

The various operational data distribution modes are:

- Processing of real-time housekeeping PCM
- Recording data housekeeping data, DCS analog data, decommutated DCS data
- Processing of spacecraft stored data
- Processing of DCS analog; generally not in real-time
- Simultaneously accepting any or all of the above data flows. When data circuits are busy, data is temporarily stored in memory or tape recorded
- Command generation (by the ADPE), verification, and validation
- Routing of real-time sensor data from the NTTF for quick-look processing.

A generalized block diagram of the ERTS data distribution segment is illustrated in Figure 2-35.

Data Distribution Unit

The data distribution unit serves to route data to and from the OCC/NASCOM interface to the ADPE. The data distribution subassembly is comprised of five units: the time code translator, the signal select unit, the tape recorder patch panel, the line drive amplifier unit, and the data interface buffer (see Figure 2-36).

Line Drive Amplifier Unit. PCM and DCS analog from the wideband technical control center, PCM, DCS, and baseband wideband sensor data

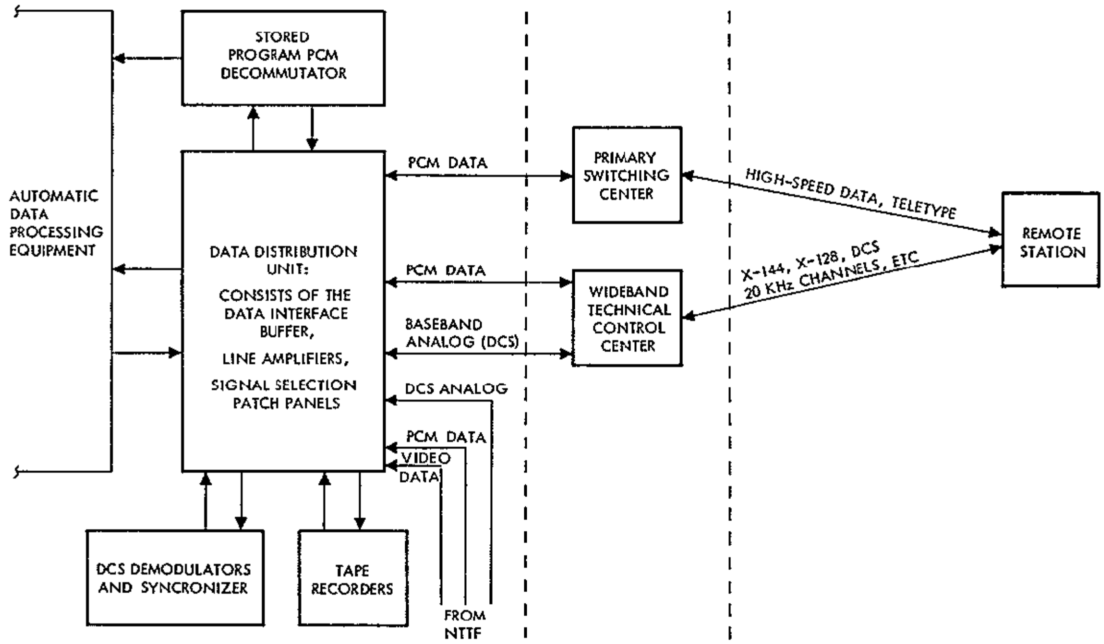


Figure 2-35

DATA DISTRIBUTION SEGMENT block diagram

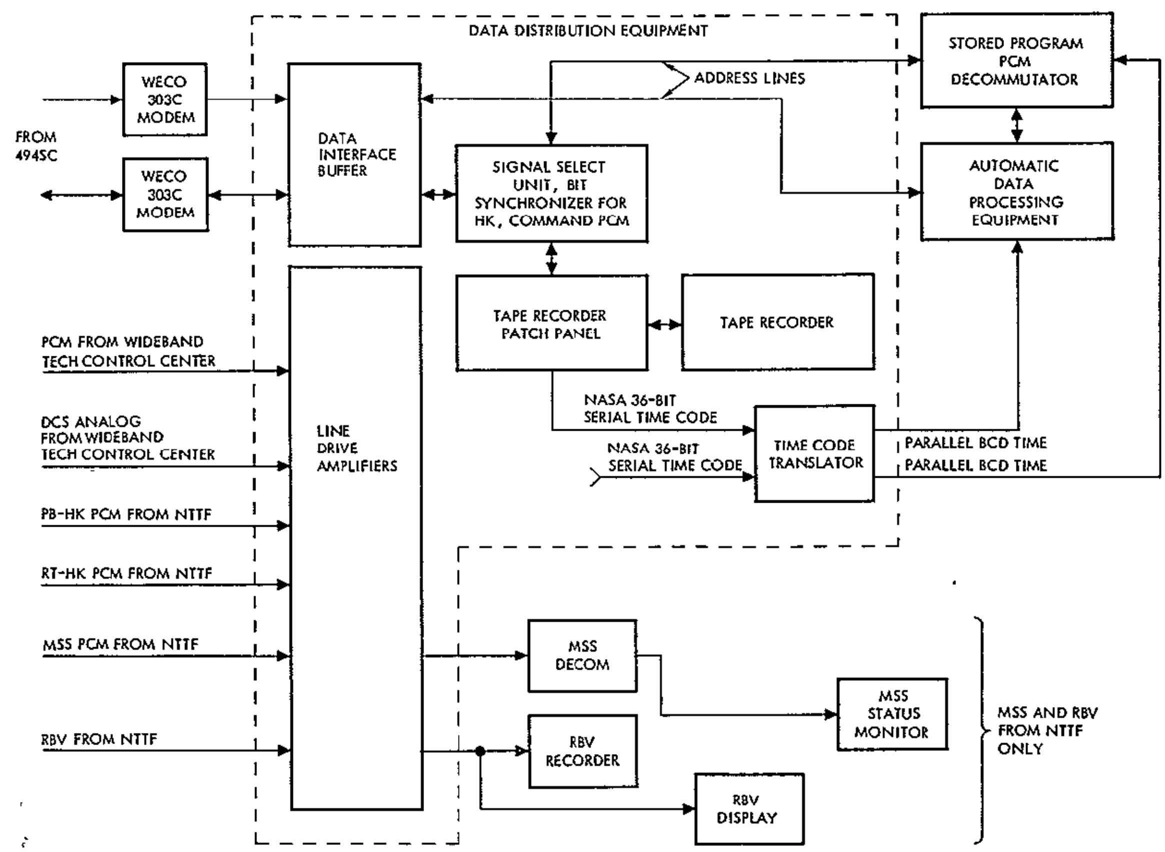


Figure 2-36

DATA DISTRIBUTION within the OCC

from the NTTF are all routed through circuit ground isolation, amplification, and data level restoration.

Signal Select Unit. The signal select unit receives all outputs of the line drive amplifier unit, all tape recorder playback signals, DCS, PCM from the DCS demodulator, and PCM from the data interface buffer. The signal select unit outputs data to the tape recorders, DCS analog to the DCS demodulator, and PCM data to the PCM data handling equipment. During tape recorder housekeeping PCM playback, NASA 36-bit serial time code associated with the HK-PCM is also output to the time code translator.

Tape Recorder Patch Panel and Tape Recorders. The tape recorder patch panel receives raw PCM, conditioned PCM, clock signals, and DCS analog signals from the signals, and DCS analog signals from the signal select unit. Outgoing command data is available from the signal select unit for tape recording; tape recording tracks are provided for OCC executive and data link voice. The tape recorders are seven-track, 1/2-inch tape machines capable of direct or FM recording.

DCS data being transmitted by slow playback over wideband circuits will be routed to a tape recorder for later fast playback to the DCS demodulator.

Time Code Translator. This unit converts NASA 36-bit serial time code to BCD parallel time code (days, hours, minutes, seconds). The BCD time code is made available for use by the ADPE and the PCM decommutator. Additionally, a "slow code" is output for time correlation recording on the six analog strip chart recorders.

Data Interface Buffer. The data interface buffer receives data from the WECO 303C modems for input to the stored program PCM decommutator or to the ADPE. The data interface buffer accepts outgoing data from the ADPE and routes it to the data modems. When the ADPE is outputting data for transmission to a remote site, the data interface buffer presents a clock control signal to the 303C transmitter modem. Operations performed by the data interface buffer on data are outlined below.

- The data interface buffer strips out the NASCOM header bits, fill sync and fill bits, and data sync bits.

- The 303C modems input data to the OCC in 50 kbit/sec bursts. The data interface buffer will temporarily store this data in memory to be subsequently output to the stored program PCM decommutator in a continuous uninterrupted serial PCM wavetrain. The wavetrain has been reformatted by the data interface buffer to be a replica of that transmitted by the spacecraft.

- Decommutated DCS PCM data will be input to the ADPE by the data interface buffer in parallel coded words.

- The data interface buffer accepts command word blocks from the ADPE at 100 kbits/sec. The command words are reformatted and routed to the 303 command link modem as 50 kbits/sec, 600-word serial data. If desired, command word blocks may be stored on tape for later transmission by tape playback.

Stored Program PCM Decommutator

The PCM decommutator receives a serial continuous PCM wavetrain formatted as a replica of the spacecraft telemetry format. The PCM decommutator strips words out of the spacecraft mainframe and routes them in parallel to the ADPE.

2.6 FACILITY PLAN

The OCC (Figure 2-37) will occupy 3333 square feet of existing computer floor area near the center of the second floor of Building 23, the main GDHS facility. The placement of rooms and work areas within the OCC promotes a logical, smooth work flow, while optimizing the interface between OCC activities and the NDPF and related support functions. Maximum use is made of the existing facility and utilities. Few modifications will have to be made; all of the 3333 square feet will be usable space; and locating the facility on a computer floor will eliminate the need for expensive raised computer design and associated cabling.

2.6.1 OCC Configuration

The OCC consists of the following areas:

- Control Room (Figure 2-38). The glass-enclosed control room is the main command and control area. It will be insulated from noise and interruptions, essential during critical operations, yet will be close to the OCC planning and support areas.

- The Pre-Pass/Post-Briefing Room. This room will adjoin the OCC control room and the operations planning and telemetry analysis room. It will serve for personnel briefing and reviews.

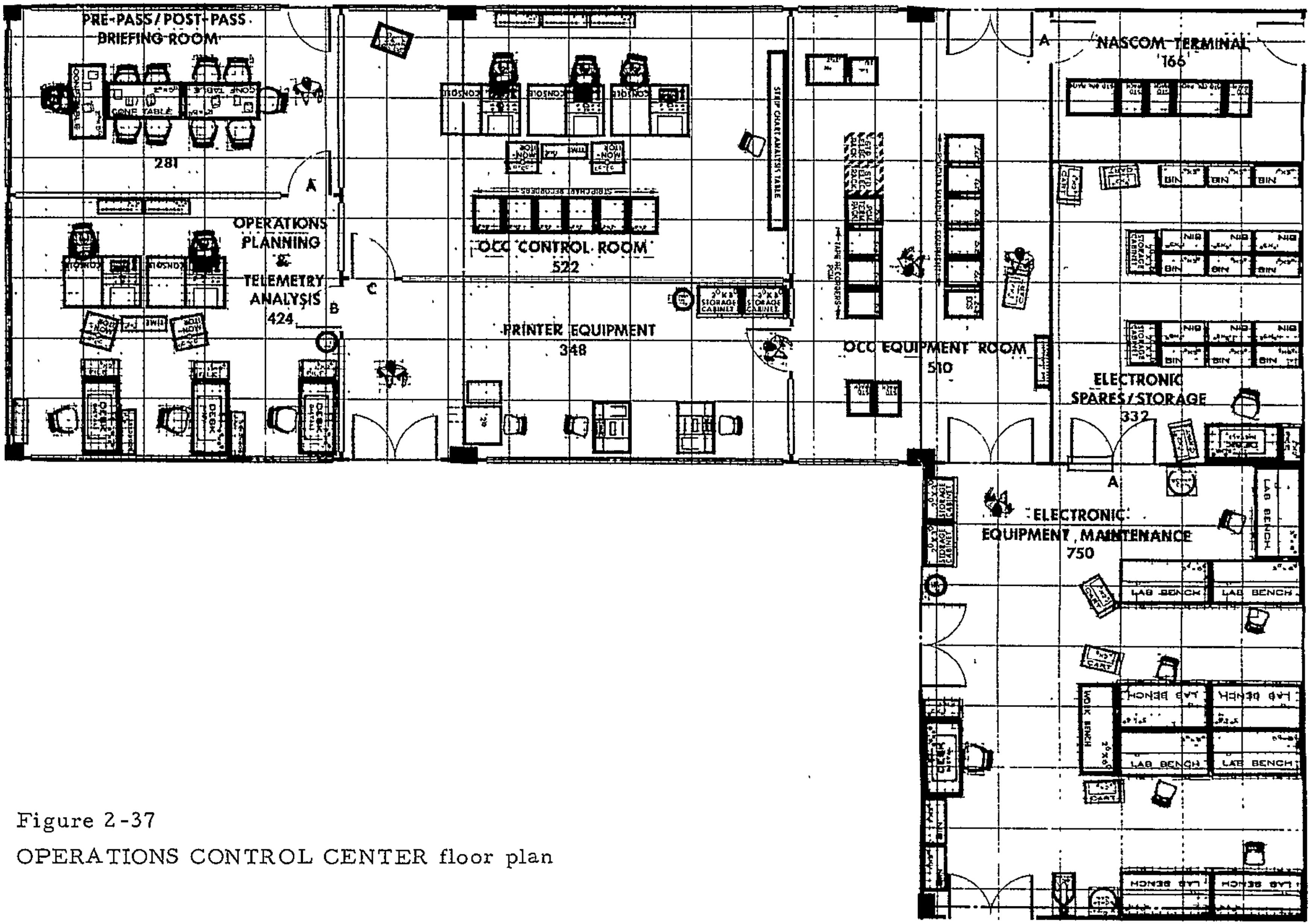


Figure 2-37
OPERATIONS CONTROL CENTER floor plan

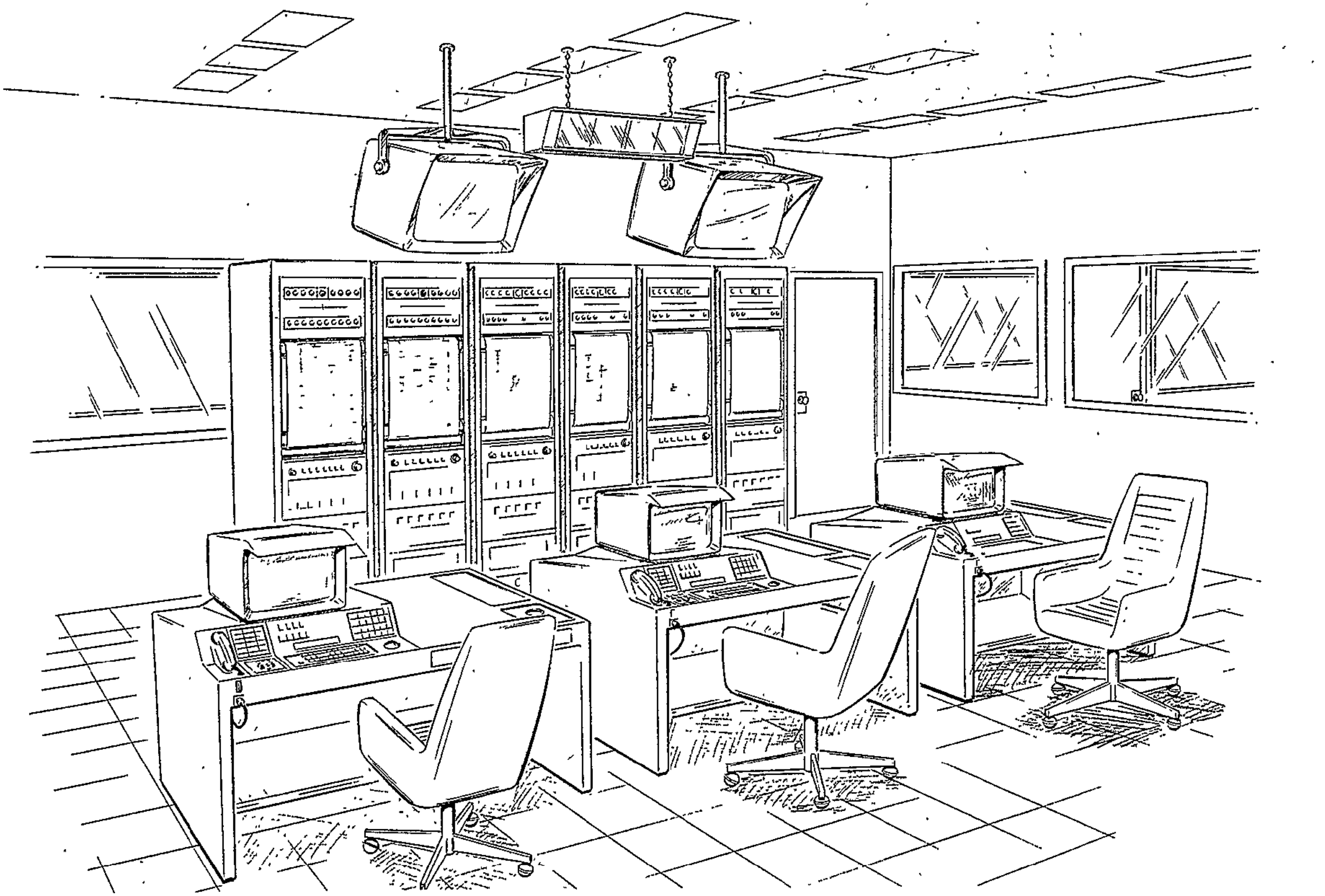


Figure 2-38

OCC CONTROL ROOM sketch

During critical events, it provides visual access to all critical areas. This room will also serve as a visitor observation area, but will not interfere with OCC operations.

- The Operations Planning and Telemetry Analysis Room. This room along with the briefing room, will provide direct support to the control room. It will be completely enclosed but has visibility into the control room which is just a few steps away. Here missions will be planned and reviewed and spacecraft data received in the control room will be analyzed.

- Printer Equipment. This room is centrally located adjoining the control room, which it supports. Insulation prevents noise generating equipment, such as computer readout equipment, from disturbing control room activities.

- OCC Equipment Room. This room will be visible to both the control room and the printer equipment room. Electronic racks, recorders, and other control center support items will be located in this room.

- NASCOM Terminal Room. This room joins the OCC equipment room. It also exists on the main corridor. It will be used to interface TRW equipment and NASA communications links. The location of this room minimizes cabling requirements and maximizes outside access.

- Electronic Spares/Storage. This room will contain all critical spare parts and supplies to support the OCC and the data services laboratory.

- Electronic Equipment Maintenance Room. This room is shared by both the OCC and the data services laboratory providing easy access to both areas.

2.6.2 OCC Space Utilization Plan

All of the 3333 square feet of space designated for the OCC operations will be usable. The space allocation is listed below:

	Square Feet
OCC control	522
Pre-pass/post-pass briefing room	281
Operational planning and telemetry analysis	424
OCC equipment room	510
Printer equipment room	348
NASCOM terminal room	166
Electronic spares/storage	332
Electronic equipment maintenance	750
Total	3,333

2.6.3 OCC Facilities Modifications

The OCC design makes maximum use of the existing facility and utilities some of which require no modifications, such as:

- The computer floor system
- The electrical system
- Most of the lighting system
- The computer floor air supply system.

The following modifications will be required.

- Relocation of the existing walls and doors
- Provision of observation windows in the control room
- Provision of a technical grounding grid under floor
- Minor lighting modifications in operating rooms.

2.7 HARDWARE DESCRIPTION

The following paragraphs describe in some detail the principle equipment within the OCC. The appendix to this volume contains preliminary equipment and system specifications, whereas the unified display systems is discussed in section 4 of this volume. Automatic data processing equipment configurations is found in section 5 of this volume.

2.7.1 Communications Equipment

The communications equipment provides for voice communications within the OCC and for voice and data communications to and from the OCC. It consists of the following items:

- Communications distribution rack
- Intercom equipment
- Teletype terminals
- Telephones
- Associated cabling.

The intercom equipment consists of a master station plus rack- and wall-mounted operator stations and monitors. Performance characteristics of all intercom equipment are as follows:

- The intercom station will impose a high impedance to the low impedance audio line, thus allowing a large number of stations to operate simultaneously.

- The intercom station performance will be such that the failure of an individual station amplifier will not cause the failure of other stations connected to the same channel.

- All audio lines will be preloaded by 620 ohms ±5 percent at one place in the system.

- The crosstalk level between channels will be at least 45 db down from 0 dbm with a +6 dbm input into the line of an adjacent channel.

- Each network will have the capability of accommodating as many as 200 or as few as two stations.

- The equipment will operate with noise-cancelling dynamic type headsets; the microphones will be 5 ohm and the receivers 20 ohm.

- The equipment will operate from a central, external dc power source.

A circuit diagram and sketch of the master station are shown in Figure 2-39. Functions of the master station include:

- Active function. The station will permit the operator to transmit and receive on any one of 10 channels selected by push-buttons. The operator will be able to monitor his transmitted signal in the headset receiver. A volume control will be provided in the receive circuit.

- Paging function. A momentary switch will be provided to permit the operator to switch the transmit signal from the intercom to the paging circuit and, at the same time, to mute the speaker at the paging station while in the page transmit mode.

  The page receiver-amplifier will be identical to the net receiver amplifier. The output signal from the speaker will be a minimum of 95 db at maximum volume settings, and a maximum of 70 db at minimum volume settings measured with a sound level meter located 6 inches in front of the speaker.

- Auxiliary function. The station will permit the operator to monitor an auxiliary function in his binaural headset in addition to the active function described above. An alternate action switch will be provided to transmit the auxiliary function on this circuit. The circuit carrying the auxiliary function will be electrically isolated from the intercommunication system. The auxiliary function will be designed to have priority over all other functions in this station.

- Conference function. The station will permit the operator to interconnect any combination of channels by the use of alternate action type push-button switches. The auxiliary function will not be a part of the conference function.

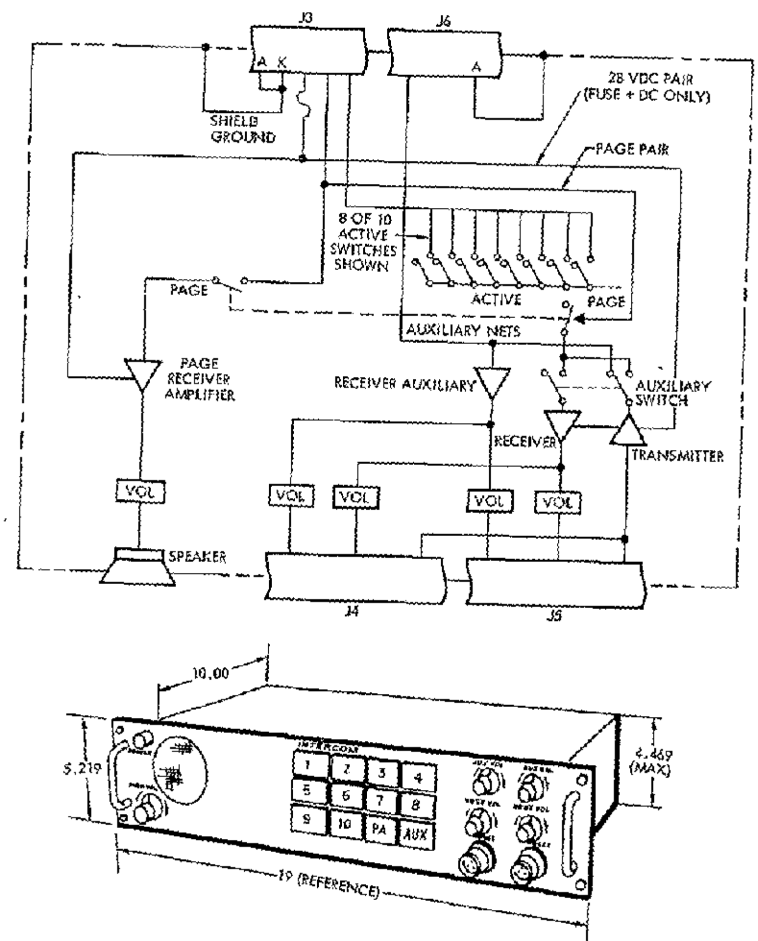
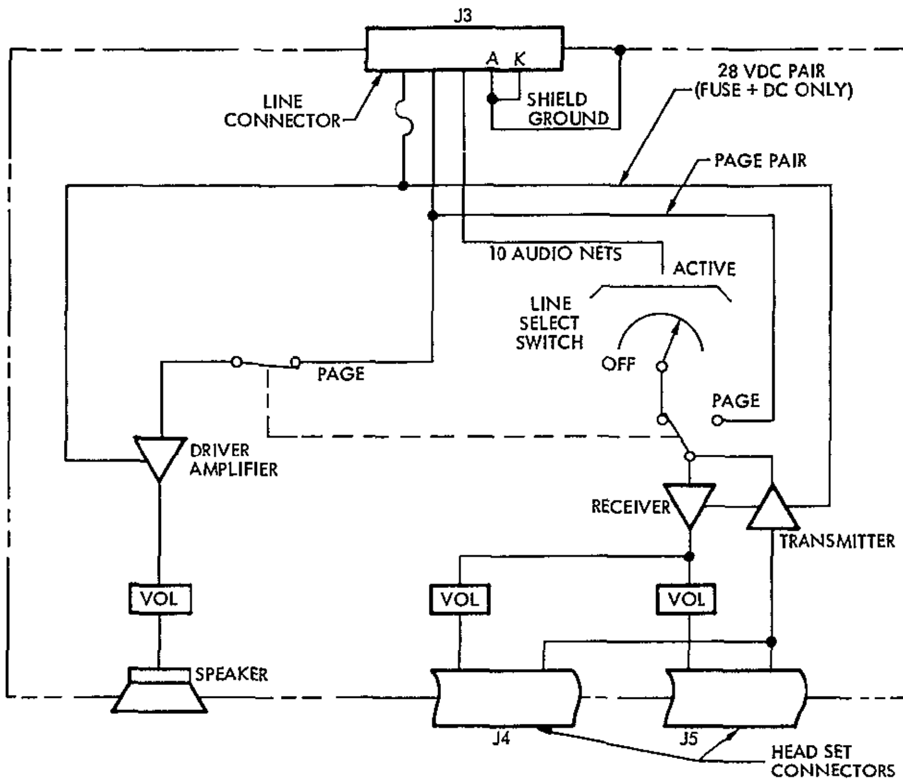


Figure 2-39

MASTER STATION with monitor

The rack-mounted operator station and monitor will provide the identical functions and be of the same design. The wall-mounted operator station and monitor has the same functions with the exception of auxiliary and conference above. As shown in Figure 2-40, this unit has a rotary switch rather than push-buttons for switching.



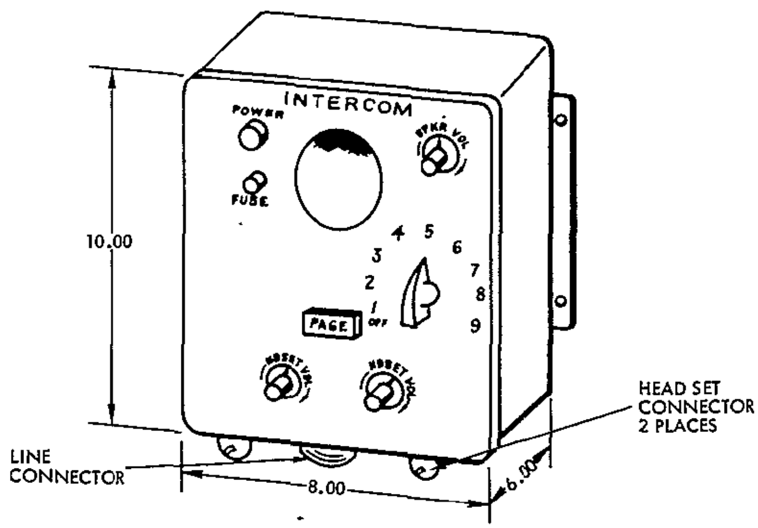


Figure 2-40

OPERATOR STATION with monitor wall-mounted

These units will use standard commercial components and will be interchangeable without rework. Headsets will be safety wired to stations to prevent unauthorized removal and provision will be made to hang them at the stations. Signal grounds will be isolated from chassis grounds, with single-point grounding at the power supply. Provisions will be made for the addition of more stations in the future without rework.

Teletype terminals will be of the automatic send-receive type with page printer and auxiliary reperforator capability. The recommended type is Teletype Corp. Model M-28, with the features listed in Table 2-9. Standard desk-type rotary dial telephones will be used for telephone communications.

Table 2-9. Teletype Terminal Features

1)	Five-level 7.42 unit code
2)	8-1/2 inch width friction feed platen
3)	Unshift-on-space may be disabled if desired
4)	Keyboard lock on "bland-blank"
5)	Automatic carriage return and line feed
6)	Signal bell on upper case "S"
7)	Standard communications typebox, typewheel, and keytop arrangement (includes blank keylever)
8)	Local carriage return and line feed mechanism
9)	Control switch for keyboard, keyboard and tape, or tape only operation
10)	Keyboard with single contact signal generator (spark suppression network)
11)	Electrical signal line break mechanism
12)	Tape backspace mechanism
13)	Typing perforator with 11/16 inch width, five-level printed chadless tape ouptut
14)	Single contact box (spark suppression network) transmitter-distributor for reading five-level (11/16 inch width) chadless or fully-perforated tape for on-line transmission of the 7.42 sequential start stop code, end of tape, and taut tape stop mechanisms, on/off switch with position to release the feed wheel and universal clutch magnet for eight ac or dc operation.
15)	Electrical service assembly with line shunt relay, line relay mounting, 120 vdc, 120 ma rectifier, line test key, and cables to interconnect set components
16)	Copyholder
17)	110-volt 60-cycle synchronous motor with drive parts for 60, 75 and 100 words/minute operation (45.5, 56.9 and 74.2 bauds)
18)	Floor model console cabinet for housing set components (includes copylight system and signal bell) with gray smooth finish
19)	Auxiliary typing reperforator with five-level, 7.42 unit code
20)	11/16 inch width chadless tape output with printing over the one- and two-levels
21)	Backspace mechanism
22)	Remote control dc blank non-interfering tape feed out
23)	Standard communications type-wheel arrangement "AWA"
24)	110-volt 60-ac synchronous motor unit with gears for 60, 75 or 100 words/minute operation (45.5, 56.9 and 74.2 bauds)
25)	Tape out, tape feed out, and off/on switches, control panel
26)	Electrical service assembly with line relay mounting, line shunt relay, signal bell assembly, and 120-volt dc, 120 rectifier

2.7.2 Data Distribution Equipment

The data distribution equipment consists of five drawers mounted in a rack:

- Time code translator
- Signal select panel
- Tape recorder patch panel
- Line drive amplifier
- Data interface buffer.

The overall configuration of the equipment is shown in Figure 2-41. The data interface buffer is relatively complex and is described in Section 2.7.3.

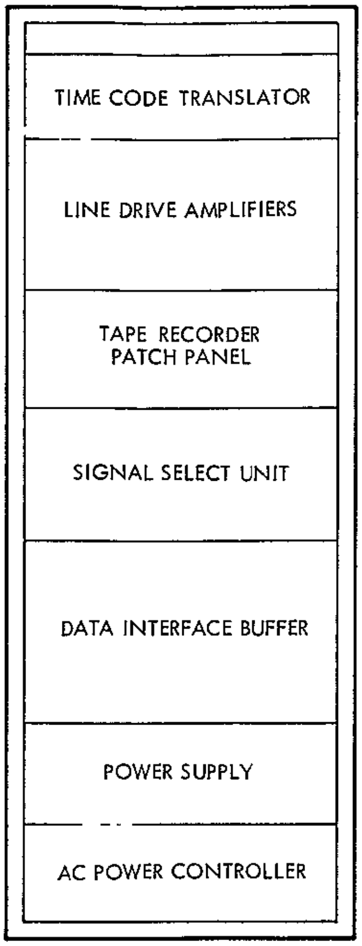


Figure 2-41
DATA DISTRIBUTION RACK

2.7.2.1 Time Code Translator

Input and output characteristics of the time code translator are as follows:

Inputs

- Accept the NASA 36-bit serial time code previously generated and recorded on magnetic tape
- Accept the same code in real-time.

Outputs

- Parallel BCD code (days, hours, minutes, seconds) to the OCC computer and to the PCM data handling equipment. This consists of 42 lines of BCD data defining the contents of the time accumulator from milliseconds through days.

  Logic level: binary "0" = 0 ±0.5 volt, binary "1" = +5 ±1.0 volts

  Max. external load: 2000 ohms

  Propagation delay: ambiguity typically 500 ns

- Serial "slow code" for time correlation on six analog strip chart recorders of ~1 megohm input impedance each

  Standard output pulse rates 1 kpps, 100, 10, 1 pps

  Amplitude: +5 volt pulses from a 0 ±0.5 volt baseline

Duty cycle: 20 percent

Max. external load: 2 kohms

Rise and fall times: <1 microsec

Pulse-to-pulse jitter: 500 ns

- NASA 36-bit visual recorder code multi-rate to permit user selection of time and pulse rate.

  Pulse rates: 50, 5, 1, 0.1 pps

  Time frames: 1 sec, 10 sec, 1 min, 10 min

  Format: pulse-width modulated BCD for seconds, minutes, hours, days

  Amplitude: +10 volt pulse from a 0 ±0.5 volt baseline

  Maximum external load: 100 ohms

- Modulated carrier code for redubbing (normalized output of AGC amplifier, identical to input code)

  Amplitude: 5 volts peak-to-peak

  Maximum external load: 2000 ohms

2.7.2.2 Signal Select Panel

The signal select panel's inputs and outputs are as follows:

Inputs

- All line drive amplifier outputs
- DCS IF simulator output
- DCS playback from tape recorders
- Housekeeping telemetry playback from tape recorders
- Conditioned housekeeping PCM and clock
- Conditioned DCS PCM and clock
- Serial time from PCM tape recorders and serial GMT from NASA time interface.

Outputs

- Signal switching to tape recorder patch panel
- Signal switching to DCS modulator and synchronizer

- Signal switching to bit sync
- Time switching to time code translator.

The signal select panel provides the following capabilities:

- Selective switching of signals from the line drive amplifier to a specific patch on the tape recorder patch panel
- Switching of the following signals from the line drive amplifier to the bit synchronizer:

  Real-time or playback housekeeping PCM data from NTTF

  Wideband housekeeping or DCS from Alaska or Rosman

  Housekeeping or DCS from Texas via the modem

- Selection, during playback, or row data from track No. 4 of the PCM tape recorders
- Switching of the signal from the DCS IF simulator to the DCS demodulator
- Switching of time code from NASA real-time or PCM tape recorders to the time code translator.

2.7.2.3 Tape Recorder Patch Panel

The tape recorder patch panel inputs and outputs are as follows:

Inputs

- Any combination of line driver amplifier outputs (raw data, conditioned PCM, and clock) through the signal select panel
- OCC voice from intercom to data links
- Generated commands
- Auxiliary inputs.

Outputs

- Any input signal to tracks 1, 3, 4, 5, 7, and E for all three PCM tape recorders
- OCC voice from intercom and data links during receiving and playback
- Intercom
- Auxiliary outputs.

2.7.2.4 Line Drive Amplifier

Inputs to the line drive amplifier will all have an impedance of 135 or 100 ohms matched to 500 ohms minimum. Output formats will be essentially the same as the input formats listed below, since the amplifiers are drivers only and do no signal conditioning. Output impedance will be nominal 75-ohm single-loaded, and output level will be 6 volts peak-to-peak from open circuit or 3 volts peak-to-peak into a 75-ohm load. In the case of the high-speed data modem, output will be mark 5v, space 5v. Input and output signals will be as follows:

Inputs

- DCS on coaxial cable from NTTF: bandwidth 25 to 125 kHz, signal level 1 volt peak-to-peak
- Real-time housekeeping PCM on coaxial cable from NTTF at either 1 or 32 kbits/sec and 1 volt peak-to-peak level
- Playback housekeeping PCM on coaxial cable from NTTF, 32 kbits/sec, 1 volt peak-to-peak level
- Wideband housekeeping or DCS PCM from Alaska or Rosman at 130 kHz or 1 or 32 kbit/sec split phase (Rosman), or 48 kHz or 1 or 16 kbit/sec split phase (Alaska); both 1 volt peak-to-peak
- Housekeeping PCM from Texas via modem; 1 or 16 kbit/sec, mark $\geq$23 ma, space $\leq$5 ma*

Outputs

- Real-time housekeeping PCM to PCM data handling equipment
- Playback housekeeping PCM to PCM data handling equipment
- Wideband housekeeping data to respective data handling equipment
- PCM housekeeping from Texas to respective data handling equipment
- RBV data to NDPF
- MSS data to MSS demultiplexer.

*100 ohms input impedance; others 135 ohms.

2.7.3 Data Interface Buffer

The data interface buffer provides data decommutation and signal level conversion of command data and telemetry housekeeping data between two WECO Model 303C data modems, the OCC computer, and the OCC data handling equipment.

The data interface buffer is functionally divided into two separate subsystems (Figure 2-42), command data decommutation between the ADPE and one 303C data modem, and telemetry housekeeping decommutation between the remaining 303C data modem and the data handling equipment.

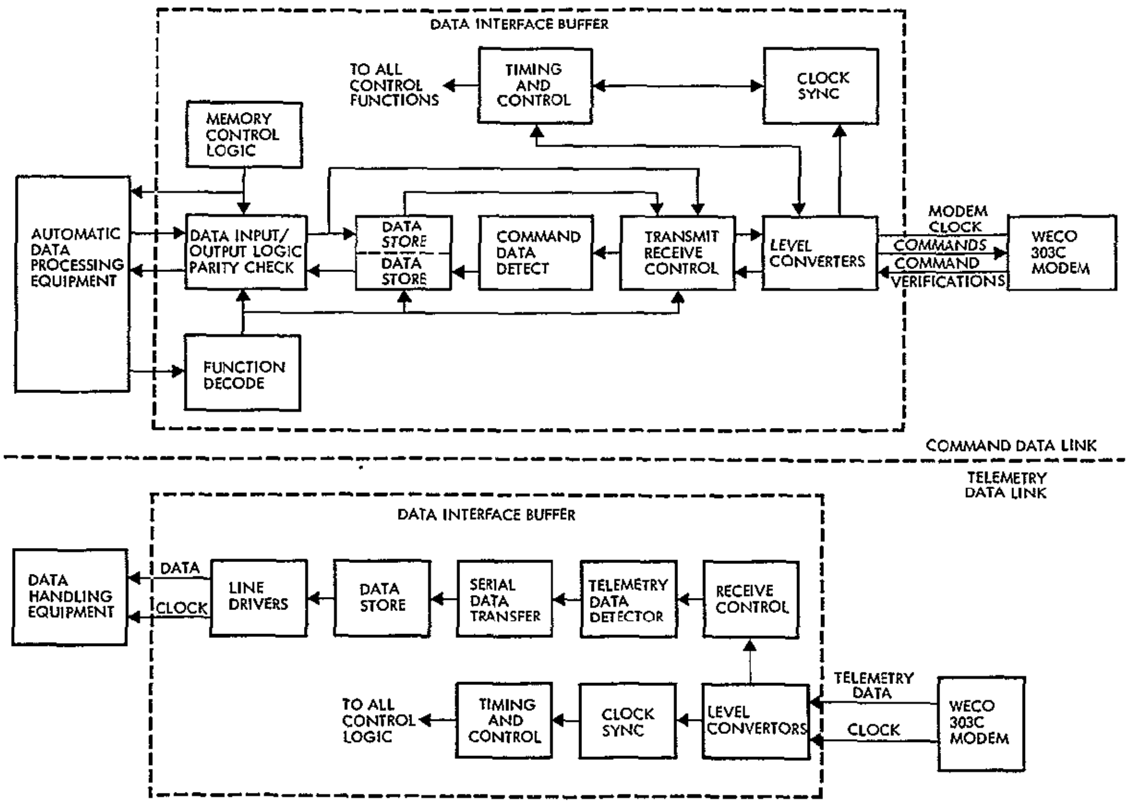


Figure 2-42
DATA INTERFACE BUFFER data flow diagram

Command data sent to the STADAN and MSFN ground tracking stations for relay to the ERTS spacecraft originates in the OCC computers (ADPE). The data interface buffer receives command data from the

computer in the form of a 9-bits parallel word consists of eight data bits plus one parity bit. The data interface buffer data input/output and parity check logic converts the 9-bit parallel word into a serial form, checks for correct parity, removes the parity bit, and transfers the eight remaining bits into a data store memory module. This process is repeated until the memory contains 600 bits of command data.

The data interface buffer timing and control logic then generates a request to send signals to the 303C modem for transmission of the 600-bit serial block of data at the required 50 kbit/sec rate.

Command verification data received from the 303C modem is a steady stream of serial data in the format illustrated in Figure 2-42. The data stream contains the 600-bit block command data transmitted to the STADAN/MSFN tracking stations plus fill sync bits necessary to keep the 303C modem receive-transmit clock in sync.

The data interface buffer receives the 50 kbit/sec serial data stream from the 303 modem through the data interface buffer transmit/receive control logic and transfers the data into the command data detection logic.

Since the computer requires only the 600-bit block command data, the command detect logic detects the command and extracts the data for transfer to the computer.

The command detect logic accomplishes this by performing a comparison check on 24 bits of data each time a data bit is received until the 24-bit command sync word is detected.

When the command sync word is detected, the data interface buffer timing and control logic transfers the command data into the data interface buffer memory store module. At the completion of a 600-bit data block transfer from the 303C modem, the command verification data contained in the data interface buffer memory store module is transferred into the data input/output logic, assigned a parity bit, and transferred to the computer in the form of a 9-bit parallel word. The data interface buffer to computer serial/parallel conversion is repeated until all 600-bits of command verification data has been transferred.

Telemetry data received from the 303C modem (Figure 2-43) is similar in form to the command verification data and is treated in the same manner. The data interface buffer receives the 50 kbit/sec serial data stream from the 303C modem via the data interface buffer receive control logic and performs an eleven bit comparison of the data each time a bit is transferred from the 303C modem. When the 11-bit data sync word is detected, the telemetry data is extracted and transferred into the data interface buffer data store module.

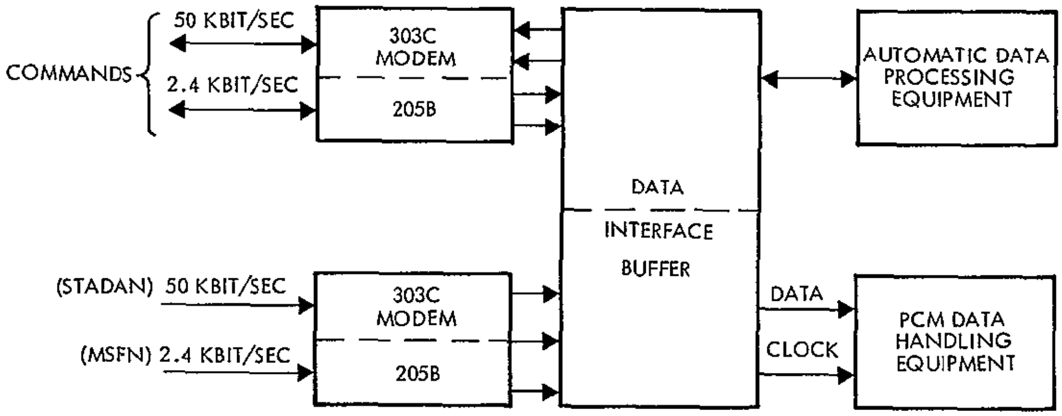


Figure 2-43
SIGNAL INTERFACE - data interface buffer

Since the data handling equipment can only process the telemetry data in the form received from the spacecraft, the data detection-extraction process is repeated until the data interface buffer memory contains the complete 1152-bit telemetry data frame. At this time, the data interface buffer timing and control logic transfers the 1152-bit data block serially into the data processing equipment at the selected 1 or 4 kbits/sec.

2.7.3.1 Data Interface Buffer Operation Functions

The data interface buffer is designed to accomplish the following functions:

Command Data Link

1) WECO 303C Modem Interface

- Receives a continuous data stream at 50 kbits/sec
- Discriminates between transmitted data and that data which is used to maintain the modem receive clock synchronization

- Detects received data by recognition of the NASCOM 24-bit header sync word which is the first 24 bits of the NASCOM 600-bit data blocks (i. e., continuous detection)

- Provides level conversion and termination impedance for the $\geq$ 23 ma, 100 ohm binary zero, and $\leq$ 5 ma, 100 ohm binary one signals which are transmitted and received on the user side of the WECO 303C modems

- Transfers 600-bit blocks of data received from the computer to the WECO 303C modem

- Provides compatible control line interfaces for transmit/ receive date

2) Computer Interface

- Processes and transfers detected data to the OCC computer in 8-bit plus parity transfer words at 100,000 words per second

- Receives parallel data from the computer and transfers this data to the WECO 303C modem in a direct mode or in direct mode as selected.

- Receives and decodes and function instructions from the computer. These instructions are contained in subcode bits of the data interface buffer address

- Provides manual control of mode and function

Telemetry Data Link

1) WECO 303C Interface

- Same as those stated in first time items of command data links

- Detects received data by recognition of the NASCOM-DTS 11-bit data sync word which is followed by 64 bits of data in each data frame of the 600-bit data block

- Reformats detected data in a serial form identical to that received at the remote sites, (i. e., spacecraft main frame)

- Provides impedance matching, signal conversion, control and monitor of modem interface lines.

2) PCM Data Handling Equipment Interface

- Transfers reformatted data to the PCM data handling equipment at 1 or 4 kbits/sec rate selectable from data interface buffer control panel

- Provides clock and control functions as required.

- Provides level conversion and signal line drive compatible with the data handling equipment.

3) Telemetry Data to Interface

- Provides capability to transfer reformatted PCM data to the computer in 8-bit and parity words at 100, 000 words per second rate.

- Provides manual selection of data routing (Data handling equipment or computer)

4) Test Modes

- Closed-loop test capability with data flowing from computer to data handling equipment via data interface buffer.

- Closed-loop test from data interface buffer to WECO 303C to data interface buffer via the local test loop in the 303C.

2.7.3.2 Signal Interface Description

A brief description of each interface signal between the WECO 303C data modems, data interface buffer, data handling equipment and computer is given below.

1) 303C Modem Unit Interface Signals (Figure 2-44)

- Request to Send signal is generated by the data interface buffer unit when the data interface buffer unit is ready to transmit data.

- Clear to Send signal from the 303C modem unit indicates that it is ready to receive data from the data interface buffer unit.

- Send Data signal is the actual data being transmitted from the data interface buffer to the 303 modem. Data is transferred to the 303 modem at 50 kbits/sec.

- Data Set Ready signal indicates that the power to the 303C modem is on and ready to process data.

- Receive Data signal is the actual data being transmitted by the 303C modem to the data interface buffer unit.

- Serial Clock from the 303C modem is 50 kHz and is used to clock data between the 303C modem into the data interface buffer.

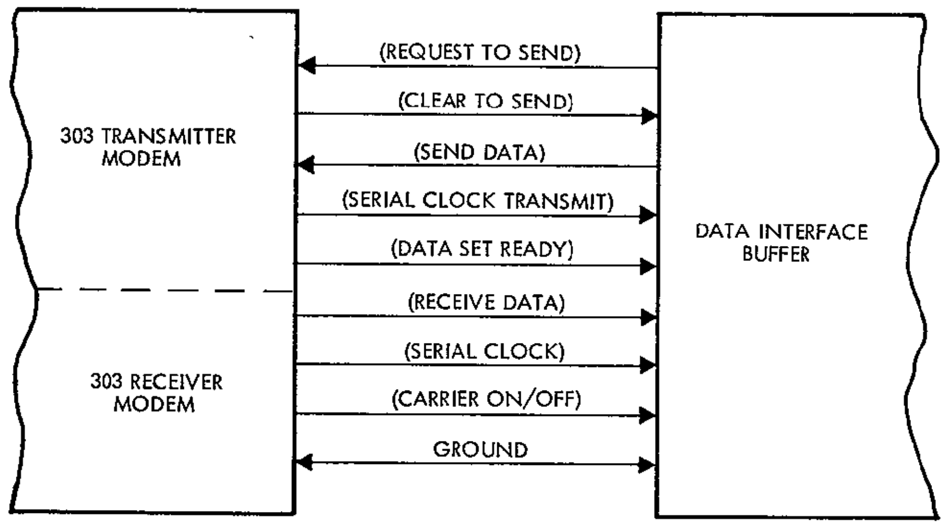


Figure 2-44
MODEM INTERFACE - data interface buffer

- Carrier On/Off signal provides an indication that data carrier signals from the remote station are being received.

- 303C Local Test signal is transmitted from the data interface buffer to the 303C modem to set the modem in the test configuration.

- AGC Lock signal received from the 303C modem provides an indication of signal quality, and is used by the data interface buffer to enable or disable data transfer from the 303C modem. When the signal is on, it indicates that the signal received by the modem over the telephone facilities have an adequate amplitude.

2) Data Interface Buffer - ADPE Interface Signals (Figure 2-45)

- Memory Address - Eleven lines of memory address information from the data interface buffer unit to the computer memory.

- Input/Output Response - One line from the data interface buffer to the computer responding to function address data received.

- Function Address - The three function address lines from the computer are fed into the function decode logic of the data interface buffer for use in the program controlled mode.

- Address Strobe - One line from the computer is used to strobe the function address into the data interface buffer.

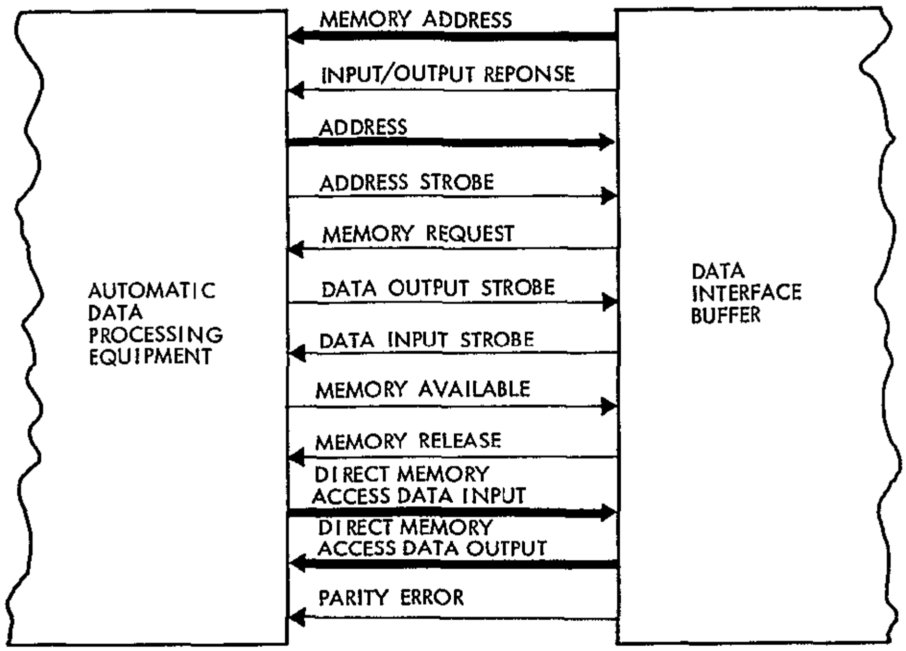


Figure 2-45

ADPE INTERFACE - data interface buffer

- Memory Request - One line from the data interface buffer requesting the computer memory.
- Data Input Strobe - One line from the computer used to strobe the computer data output register in the data interface buffer.
- Data Output Strobe - One line from the data interface buffer used to strobe the data on the computer input lines into the data input register.
- Memory Available - One line from the computer indicating that the computer memory is available to the data interface buffer.
- Memory Release - One line from the data interface buffer to the computer to release memory after a data transfer.
- DMA Data Input - Eight lines of data and one parity bit line from the computer.
- DMA Data Output - Eight lines of data and one parity bit line from the data interface buffer.
- Parity Error - One discrete line from the data interface buffer to the computer indicating parity error.

- Start Test - One discrete line from the data interface buffer to initiate the closed loop data flow test when controlled from the data interface buffer front panel.

- Test Status - One discrete line from the computer to indicate the test results.

3) Data Handling Equipment Interface Signals

- Data - One line from the data interface buffer to the data handling equipment for 1 or 4 kHz serial data.

- Serial Clock - The serial transfer clock from the data handling equipment used to clock data from the data interface buffer to the data handling equipment.

2.7.3.3 Data Transfer

Data decommutation and transfer through the data interface buffer is divided into three functional parts: command data link, PCM telemetry data link, and data transfer closed-loop test.

Command Data Link

Command data is transferred between the ADPE and the WECO 303C modem in word blocks of 600 bits via the data interface buffer unit. Data transfer within the data interface buffer is accomplished via one of two paths (Figure 2-44), directly between the ADPE and 303C modem via the data interface buffer parallel serial conversion registers or through the two data interface buffer memory modules. If the direct route is chosen (either by data interface buffer front panel control or ADPE software control), the burden of providing a constant 600-bit block data stream interface with the 303C modem is a combination ADPE-data interface buffer function depending upon the ADPE memory availability. If the ADPE-data interface buffer memory module route is chosen, the data decommutation and 600-bit block to the 303C modem is controlled by the logic within the data interface buffer unit. In the normal mode of operation, the data interface buffer memory route is used since this mode requires less computer time. The direct route used as a backup in case of a data interface buffer memory failure.

Data Signal Flow, ADPE to 303C Modem. Command data transferred from the ADPE to the data interface input register is initiated under

ADPE computer software control or manual data interface front panel control through the data interface function decode logic. The function decode logic is used to generate the first memory read request to the ADPE. Upon receiving a memory available signal from the ADPE, the data interface buffer memory address register transfers to the computer the starting location of the 600-bit block of data within the computer memory. Therefore, data interface buffer memory control logic is incremented after each word transfer.

The 9-bit parallel word (8 bits of data and 1 bit parity) from the ADPE is strobed into the data interface buffer data input register where the parity bit is stripped from the word. The remaining 8 bits of data are transferred serially from the data input register through the parity check logic to the memory-1 input control logic. If a parity error is detected, a parity error flag is sent to the ADPE and the error status displayed on the data interface buffer front panel.

The data interface buffer memory-1 input control logic gates the ADPE command data into the memory-1 module or direct to the 303C modem via the modem data select logic; depending upon the information received from the data interface buffer function decode logic.

If the data is gated into the memory-1 module, a bit counter located in the memory-1 transfer control logic signals the data interface buffer modem data control logic at the completion of a 600-bit block transfer.

When the data interface buffer is ready to transfer data to the 303C modem, a request to send signal is generated by the modem data control logic. The request to send signal is initiated either by the timing and control end of block transfer signals or memory release, depending upon the interval data interface buffer transfer mode selected.

If the 303C modem is ready to accept data, the unit sends a clear-to-send signal to the data interface buffer. The clear-to-send signal is sensed by the modem data control logic to enable the SOHZ transfer clock from the timing and control logic to the data interface buffer data input register if the direct route is chosen for to the memory-1 timing and control logic if the data interface buffer memory route is chosen.

The timing and control transfer logic provides a 50 Hz clock to the data interface buffer data input register when data is transferred directly to the 303C modem and provides a 500 Hz clock to the data interface data input register when the data is transferred to the data interface buffer memory-1 module.

Data Transfer Flow, 303C Modem to ADPE. Command data verification transfer from the 303C modem to the computer is accomplished similar to the method described above, but in the reverse order.

The serial data from the 303C modem is sent to the data interface buffer modem input control logic along with the 303C modem on/off signal. The carrier on/off signal is used as a control function for the data being gated to the command detection logic. The command detect logic contains hardwired compare-detect logic designed to recognize the 24-bit command data sync frame, extract the sync frame and the next 576 bits received from the incoming 50 kHz serial bit stream. The command sync detection is accomplished by comparing 24 bits of data each time a bit is transferred from the 303C modem to the data interface buffer. When the synch word is detected, the compare function is inhibited until the 600-bit command block has been transferred into the data interface buffer memory module or direct to the ADPE. The memory-2 input control will gate the modem data into the memory-2 module or through the ADPE data control logic to the data interface buffer data output register, depending upon the transfer mode selected and ADPE memory availability. The 303C modem command verification data parallel transferred from the data interface buffer to the ADPE is in the form of a 9-bit word, 8 bits of data plus a parity bit added by the data interface buffer.

At the completion of eight transfer pulses gating the data into the data output register, the timing and control logic generates a memory request which is sent to ADPE. Upon receiving a memory available signal from the computer, the data interface buffer memory address and control logic sets the memory address lines to the computer with the first location of computer memory in which the 600-bit blocks of data is to be stored. At the same time the data interface buffer memory control logic

generates a data output strobe to transfer the data from the data interface buffer into the ADPE.

As in the case of computer to data interface buffer data transfers, each time data is transferred from the data interface buffer into the computer the memory address counter is incremented by one.

The starting ADPE memory location in both cases is controlled by the data interface buffer front panel mounted memory address switches.

PCM Telemetry Data Link - 303C Modem to Data Handling Equipment

The PCM telemetry data received from the WECO 303C modem by the data interface buffer is in the format illustrated in Figure 2-46.

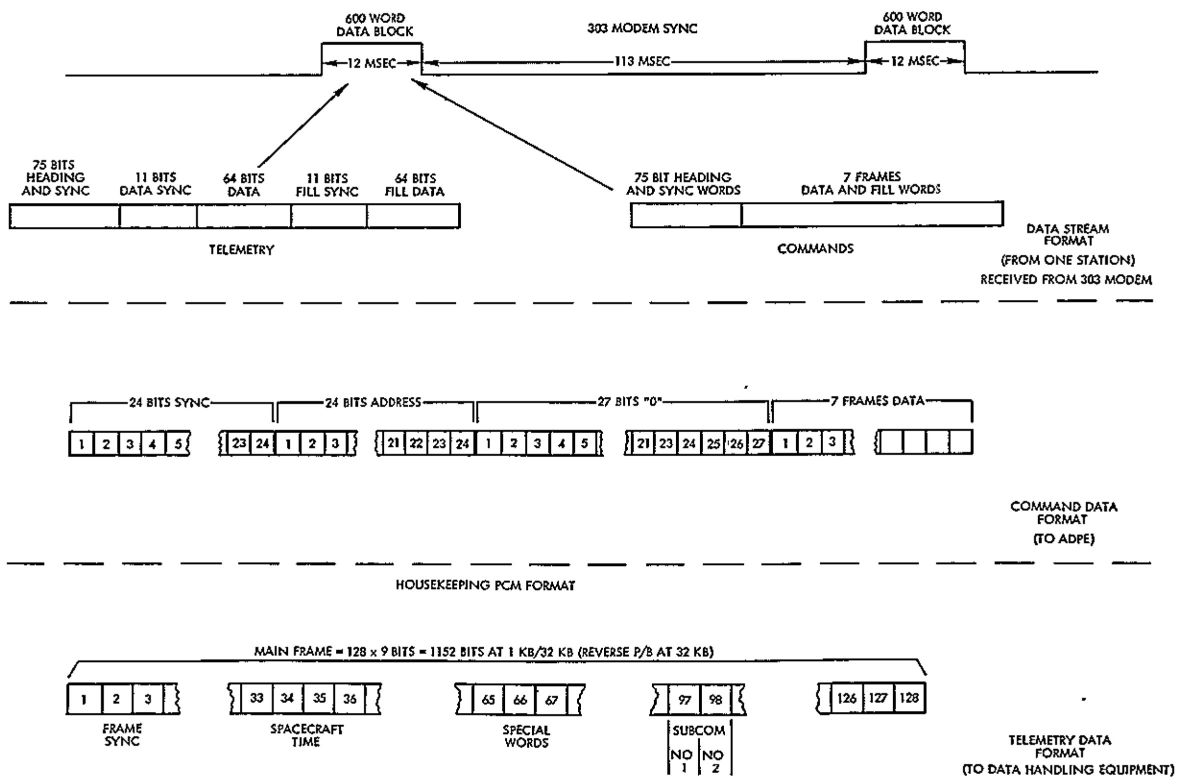


Figure 2-46
COMMAND AND TELEMETRY data stream

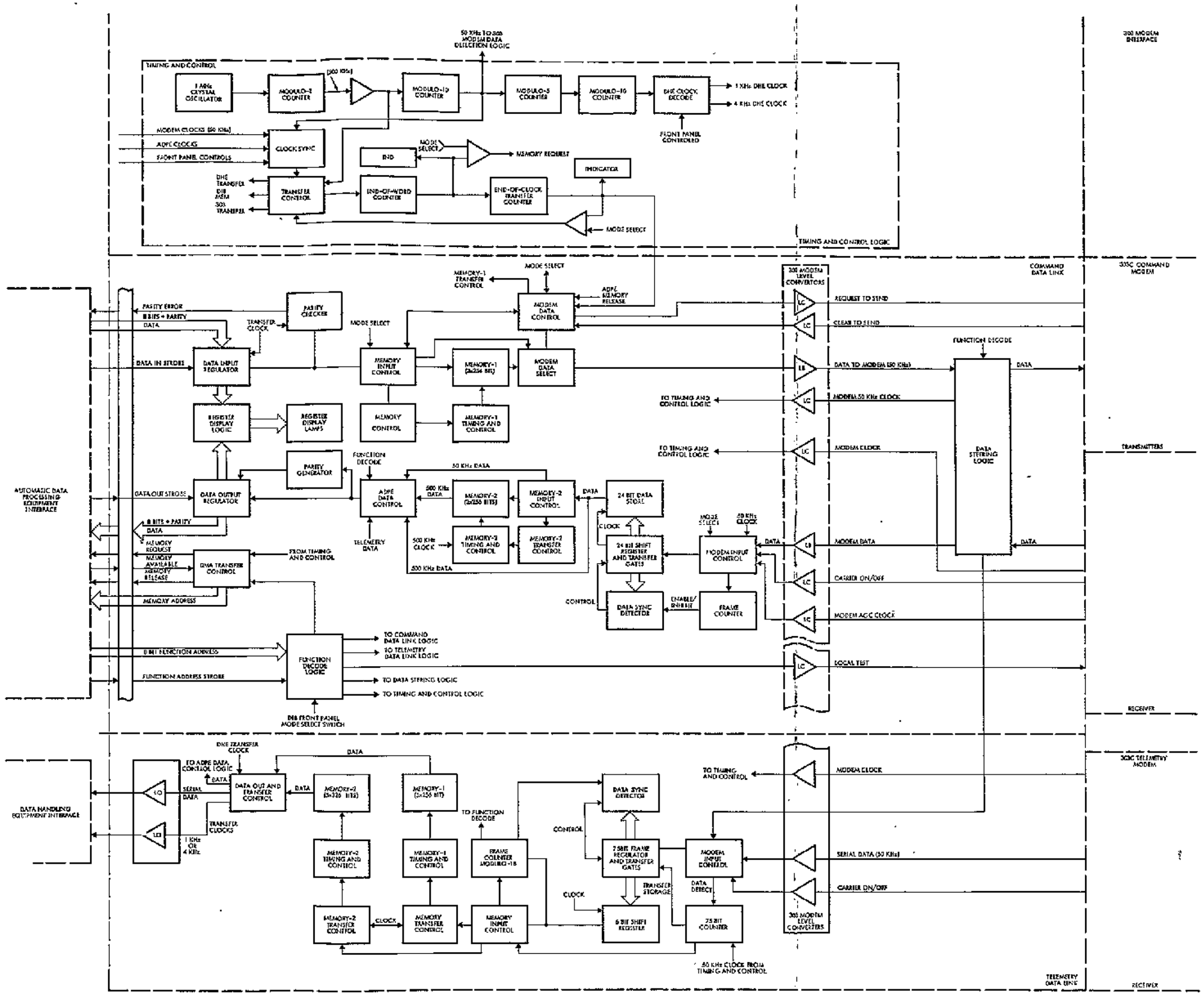
The 600-bit block of data contains eight 75-bit frames. The first 75-bit frame contains heading and address information assigned at the remote ground tracking station. The remaining seven frames of data are

a combination of spacecraft housekeeping data and block fill data with a frame data sync or fill sync 11-bit word identifying each. The remaining 64 bits (75-11) of the data sync frame is the actual telemetry housekeeping information received from the spacecraft.

Since the DHE requires only the PCM housekeeping data, the DIB removes all other information from the 600-bit block, and stores the PCM telemetry data until a 1152-bit frame of data has been reconstructed (i. e., the housekeeping data transmitted by the spacecraft consists of 128 x 9 bit words).

The incoming 600-bit serial block of data from the 303C modem and the modem clock are gated into the data interface buffer clock sync and data detection logic using the 303C modem carrier on/off signal (Figure 2-47). The modem 50 kHz clock is used to transfer the PCM telemetry data into a 75-bit frame register. The modem clock is also gated to a mod 75-bit counter which produces a pulse used to strobe the first 11 most significant bits of each frame into the fill sync and data sync detection logic. If the 11-bit sync word is decoded as fill sync data, a reset pulse is generated and sent to the 75-bit reset register and 75-bit counter. If the 11-bit sync word is decoded as data sync data, a data strobe is generated and the 64 bits of data within the 75-bit word is transferred parallel into a 64-bit serial shift register. After a two microsecond delay, the data strobe is sent to the data interface buffer serial data shift control logic which enables a 500 kHz clock to transfer the 64 bits of data into data interface buffer memory-1 module or memory-2 module via the memory control logic.

The operation described above is repeated for each 75-bit frame of every 600-bit block of data until the data interface buffer mod 18 frame counter detects a transfer of 18 64-bit words and generates an end-of-frame strobe. The end-of-frame strobe switches the serial output of the 64-bit serial shift register to the alternate data interface buffer memory module, and at the same time enables the 1 or 4 kHz transfer clock from the data interface buffer timing and control logic to shift the 1152-bit block of data serially from the data interface buffer memory module to the data handling equipment via the output data and clock control logic.



PRECEDING PAGE BLANK NOT FILMED.

FOLDOUT FRAME /

Figure 2-47
DATA INTERFACE BUFFER UNIT block diagram

FOLDOUT FRAME 2

Data Transfer Closed-Loop Test

The ADPE-data interface buffer-303C modem interface contains a built-in closed-loop test capability. This test is initiated and controlled automatically from the command operation's console or manually from the data interface buffer front panel control switches.

The test is divided into four test loops (Figure 2-48) each having the capability to isolate a separate unit interface.

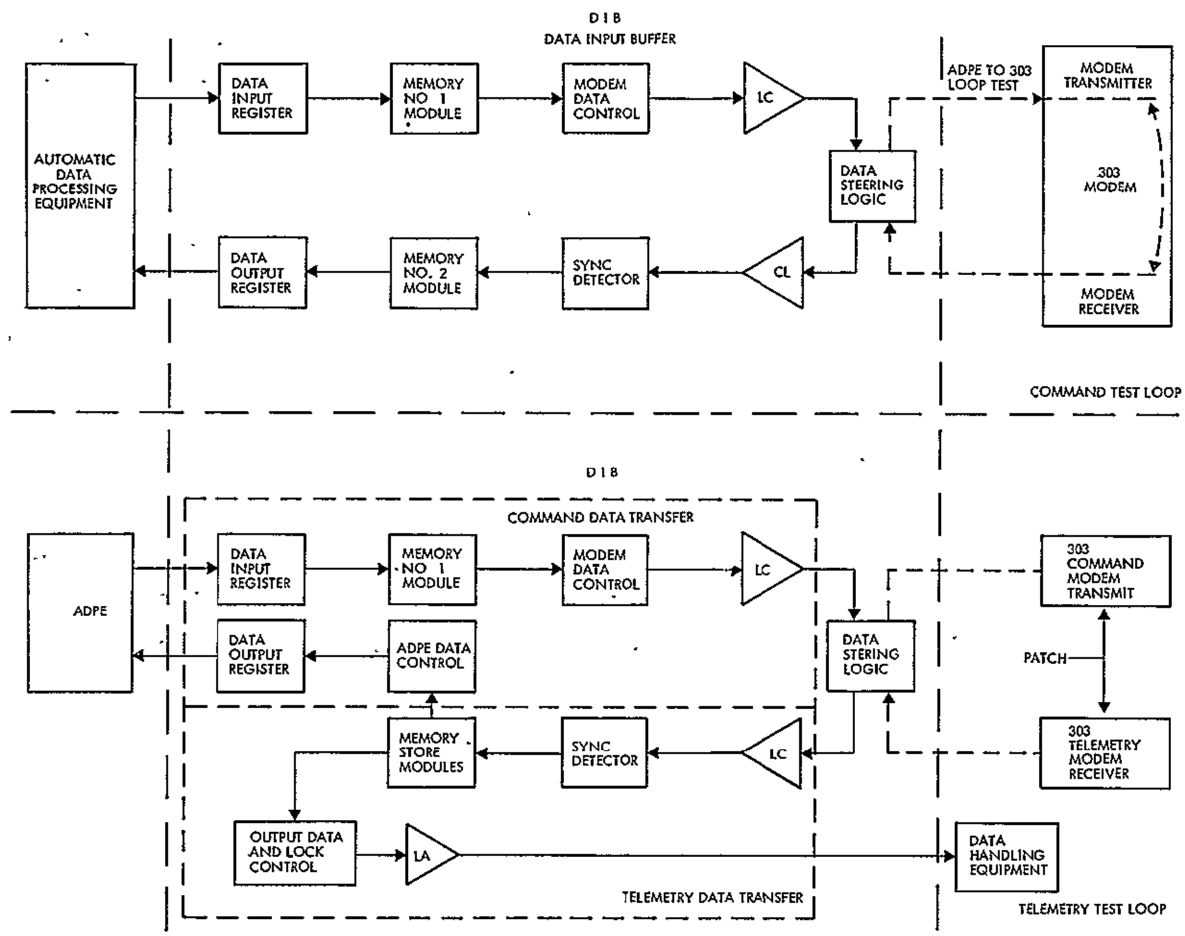


Figure 2-48
TEST DATA flow diagram

In both the automatic and manual test mode, data transfer and bit error analysis is performed by the computer. At the completion of the test cycle, a test status display located on the command operator console and on the data interface buffer front panel indicates the results of the test.

The data flow for each closed-loop test is described in the following paragraphs.

ADPE-Data Interface Buffer Command Link Test. When the test cycle is initiated, either from the command operation's console or data interface buffer front panel, the computer transfers the test function address to the data interface buffer to set logic for a command data loop test. This also generates a memory read request from the data interface buffer to start a 600-bit block transfer of data from the computer memory into the data interface buffer as described earlier.

The test function decode logic also controls the data interface buffer output steering logic to route the test data from the data interface buffer output level converter/line driver amplifiers back into the data interface buffer receive amplifiers. Data is transferred through the data interface buffer into the ADPE memory by the same method described before. The computer then compares data received with that transmitted and indicates the status of the test.

ADPE-Data Interface Buffer Telemetry Loop Test. The telemetry data loop is initiated and controlled as described in the paragraph above. Data transfer through the data interface buffer to the command link transmit amplifiers is also the same as that described. However, the test functions decode logic has changed the output steering logic to route the test data back into the telemetry link receive level converter amplifier.

The test data is clocked from the receive level converter amplifiers through the data sync detection logic into the data interface buffer memory store modules. The data is then transferred from the data interface buffer telemetry store modules through the computer command data control logic into the data interface buffer output requester for transfer to the ADPE.

The data interface buffer can also be programmed to route the telemetry test data from the telemetry link receive level converters through the data handling equipment via the normal telemetry data transfer route (i. e., through the data handling equipment line drive amplifiers).

ADPE-Data Interface Buffer-303C Modem Command Test Loop. When the data interface buffer is set for the ADPE-data interface buffer-303C modem test configuration, command data is transferred between the ADPE and 303C modem as described before, with one exception. The data interface buffer function decode logic initiates a local test signal which is transmitted to the 303C command modem. The 303C modem then reroutes the transmit telephone line side back into the telephone receive side. In this loop configuration, all three unit interfaces are tested.

ADPE-Data Interface Buffer-303C Modem Telemetry Test Loop. The ADPE to 303C modem telemetry test loop is similar to the command test loop, but requires external patching to the command 303C modem receiver side. In this test configuration, telemetry is transmitted through the command data path from the ADPE to the 303C command data modem, from the 303C command data modem telephone line transmit side into the telemetry 303 data modem telephone line receive side, and back into the ADPE through the data interface buffer as described above.

The data transfer described above is a hard-wired operation of the data interface buffer and requires no programming from the ADPE. Data interface buffer front panel controls allow the operator to select the data transfer rate (1 or 4 kbits/sec) between the data interface buffer and data handling equipment. Front panel controls also allow switching of the telemetry data into the ADPE as described in the following section.

2.7.3.4 Data Interface Buffer Front Panel Controls

The functions of each front panel switch and indicator on the data interface buffer unit are listed below (Figure 2-49):

- Register Display Indicator displays the contents of the data input register or the data output register.
- Parity Error Indicator is activated only if there is a parity error in the data received from the ADPE.
- Register Displayed Switch is used by the operator to select the register to be displayed.
- Mode Select Switch allows the operator to select the data transfer path in a manual mode of operation. When the mode select switch

is in the "program" position, the data interface buffer is under program control and all of the ADPE-data interface buffer data transfers are done automatically. The 303C-to-ADPE and 303C-to-MEM (memory) positions are controlled by the operator. The mode select switch also controls the internal test functions when in the manual mode of operation.

- Memory Address Switch is a two-section thumbwheel switch, BCD coded to allow the operator to manually address the ADPE memory. In normal operations the contents of the memory address switches are used as the starting address location of the 600-word block loaded into ADPE memory. The memory address switches are used for address and display of the contents of ADPE memory when in the maintenance mode of operation.

- Internal Test Indicator lamp is used to initiate the data interface buffer self-test mode of operation to verify the test performance. The patch board on the front panel is utilized with a pulse generator and format generator to simulate each data transfer interface.

- Single Step Switch is or-logic gated into the timing and control logic. If a failure is indicated, the operator may use the step switch to single step through the data transfer operation until the failure is detected.

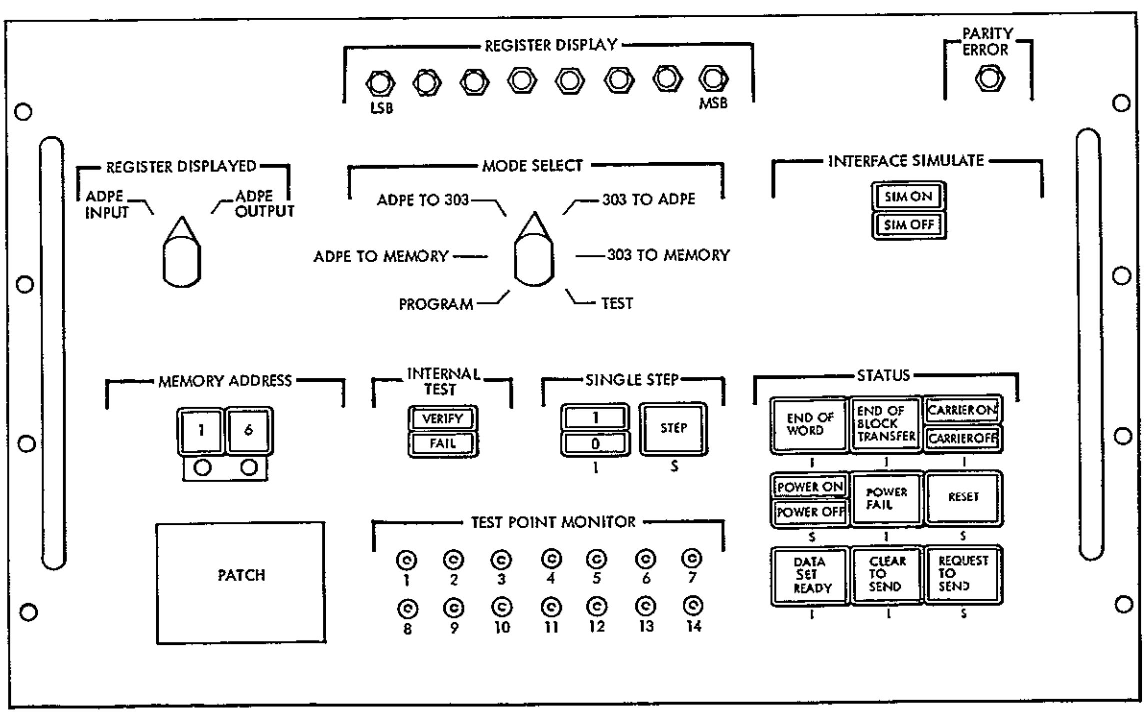


Figure 2-49

FRONT PANEL CONTROLS - data interface buffer

- Status Indicators switches (end-of-word, end-of-block-transfer) indicate the status of all of the 600-bit block transfer. The carrier on/off, data set ready, clear to send, and request to send indicate the status of the 303C modem interface into the data interface buffer. The power on/off power fail indicators, indicate the internal power status. The manually-controlled reset switch is or-logic gated to reset all logic in the data interface buffer.

- Data Sync Indicator indicates to the operator when the data sync pattern is locked in sync.

- 1 to 4 kbit/sec Switch allows the operator to select the PCM bit rate transfer from the data interface buffer to the data handling equipment.

- Carrier On/Off Indicator indicates to the operator the 303C modem unit is ready to transmit data.

2.7.4 PCM Magnetic Tape Recorders

PCM tape recorders provide the capability for recording spacecraft commands at the time they are transmitted and recording PCM and DCS data at the time it is received.

The PCM tape recorder will interface directly with the tape recorder patch panel, NASA 36-bit serial time code, reference frequency spacecraft commands and via signal select panel with the time code translator, DCS demodulator and PCM bit sync.

The interface with the tape recorder consists of the following signals

Inputs

- Commands recorded on track 1 at the time they are transmitted

- Signals listed below, depending on the mode of operation.

  1) DCS from NTTF

     Bandwidth: 25 kHz to 125 kHz
     Impedance: 75 ohms
     Signal level: 1.5 volts

  2) Real-time housekeeping PCM from NTTF

     Bit rate: 1 or 32 kbits/sec
     Impedance: 75 ohms
     Signal level: 1.5 volts

3) Playback Housekeeping PCM from NTTF

   Bit rate: 1 or 32 kbits/sec
   Impedance: 75 ohms
   Signal level: 0-3 volts peak-to-peak

4) Wideband Housekeeping or DCS from Alaska or Rosman

   Impedance: 75 ohms
   Signal: 1.5 volts
   Bandwidth: 130 kHz; 1 or 32 kbit/sec split-phase (Rosman)
   98 kHz; 1 or 32 kbit/sec split-phase (Alaska).

5) Housekeeping or DCS from Texas via Modem

   Impedance: 75 ohms
   Signal: 1.5 volts - Mark
   Bit rate: 1 or 16 kbit/sec

6) High-speed housekeeping data from NASCOM via modem

   Impedance: 75 ohms
   Signal: 5 volts
   Bit rate: 50 kbits/sec

- Conditioned PCM and clock from the bit sync via patch panel on coaxial cable and normally recorded on tracks 5 and 3, respectively. The outputs shall be regenerated serial data, split-phase, and 0 degree clock at 2.8 volts peak-to-peak balanced above ground.

- Conditioned DCS data and clock via patch panel on coaxial cable from the DCS Sync and normally recorded on tracks 5 and 3, respectively. The outputs shall be regenerated serial data and available at 2.8 volts peak-to-peak balanced about ground.

- Exec voice via patch panel from OCC usually recorded on track 7.

- Voice from data links via patch panel, normally recorded on the E-track.

- OCC intercom signal via patch panel

- Three auxiliary-inputs patchable by the operator

- NASA 36-bit serial time code normally recorded on track 6

- A sinusoidal reference signal of 1 or 10 kc depending on the tape speed normally recorded on track 2. The frequencies are used for data correlation, timing accuracy, and tape speed control.

Outputs

- DCS data and clock, 1 volt rms via switch on the signal select unit to the DCS demodulator
- PCM housekeeping, 1 volt rms via switch 53 to the bit sync
- Spacecraft commands from track 1 for verification
- Voice at 1 volt rms from tracks 7 and E for playback through the OCC intercom
- NASA 36-bit serial time code at 1 volt rms to the time code translation for distribution to the command encoder, PCM decomm, and OCC computer
- Ref. frequency at 1 volt, 1 or 10 kHz, depending on tape speed, for use as data correlation, timing accuracy, and tape speed control.

The PCM tape recorder meets all the requirements of the GSFC Aerospace Data Systems Standards #X-560-63-3, Part III, Section 4, and has the following characteristics:

- Tape speeds of 120, 60, 30, 15, 7-1/2, 3-3/4 and 1-7/8 in. /sec
- Seven-track, 1/2-inch tape
- Contains an edge track for voice recording
- Channels 1, 2, 6, 7, E, direct record electronics
- Channels 3, 4, 5 capability of direct or FM record
- Is able to play back while recording on tracks 3, 4 and 5.
- Signal electronics, direct

  Input level 0.25 to 10 volts rms

  Input impedance selectable 75, 1000, or 20,000 ohms in parallel with 100 picofarads unbalanced to ground.

  Output impedance: 75 ohms ±10 percent

  Output level: 1.0 volt rms across 75 ohms

  Bandwidth

Tape Speed (ips)	Bandwidth	RMS S/N Ratio
120	400 Hz to 1.5 mHz	30
60	400 Hz to 750 kHz	29
30	400 Hz to 375 kHz	29
15	400 Hz to 187 kHz	28
7-1/2	400 Hz to 93 kHz	27
3-1/4	400 Hz to 46 kHz	26
1-7/8	400 Hz to 23 kHz	24

- Signal electronics, FM

  Input impedance selectable 75, 1000, 20,000 ohms in parallel with 100 picofarads unbalanced to ground

  Input sensitivity: 0.5 volt peak to 25 volts peak adjust

  Output impedance: 75 ohms nominal

- Bandwidth

Tape Speed (ips)	Center Carrier (kHz)	Bandwidth (kHz)	RMS S/N Ratio
120	900	Dc to 500	33
60	450	Dc to 250	32
30	225	Dc to 125	31
15	112.5	Dc to 62.5	30
7-1/2	56.25	Dc to 31.25	29
3-3/4	28.125	Dc to 15.6	26
1-7/8	14.06	Dc to 7.8	25

- Output level: 4vpp into 75 r load ±40 percent devotion

  3vpp into 75 r load ±30 percent devotion

- Power requirements: 105 to 125 volts, 47 to 63 Hz single-phase

- Tape speed accuracy: ±0.2 percent max, long-term with input power variations from 105 to 125 volts ac, 47-63 Hz

- Fast wind time: Fast forward and reverse for 14-inch reel with 7200 feet of tape is 5 minutes. Tape is continuously under Capstan control. Tape speed never exceeds 360 in./sec.

- Time base error:

Tape Speed (ips)	Error (μsec)
120	± 1.5
60	± 3.0
30	± 5.0
15	±10.0
7-1/2	±15.0
3-3/4	±25.0
1-7/8	±30.0

- Dynamic slew:

Tape speed (ips)	T (μsec) zero-to-peak
120	0.15
60	0.30
30	0.60
15	1.20
7-1/2	2.40
3-3/4	4.80
1-7/8	9.60

- Nonorthogonal timing error (NTE):

Tape speed (ips)	NTE (μsec) zero-to-peak
120	2.4
60	4.8
30	8.6

Tape Speed (ips)	NTE (μsec) zero-to-peak
15	17.2
7-1/2	29.4
3-3/4	53.8
1-7/8	87.6

- Flutter, percent measured per IRIG 106-66 (two signal):

Tape speed (ips)	Flutter Bandwidth	Percent Flutter
120	0.2 Hz to 10 kHz	0.15
60	0.2 Hz to 10 kHz	0.15
30	0.2 Hz to 5 kHz	0.15
15	0.2 Hz to 2.5 kHz	0.25
7-1/2	0.2 Hz to 1.25 kHz	0.30
3-3/4	0.2 Hz to 625 kHz	0.45
1-7/8	0.2 Hz to 312 Hz	0.60

- Start time required to meet flutter spec is ±8 seconds at 120 ips
- Stop time is 4 seconds max at 120 ips
- Heads comply with IRIG 106-66

2.7.5 DCS Data Handling Equipment

The DCS data handling equipment is contained in one rack and comprises three drawers: the demodulator, synchronizer, and IF simulator. It also includes attendant power supplies. In the following paragraphs, the major units are given detailed descriptions. The demodulator and synchronizer are shown in Figure 2-50.

The demodulator accepts the DCS IF spectrum. It searches this for existence of carriers by a sweeping process, wherein six phase-lock loops cover the band in two identical sawtooth sweeps related by 180 degrees (Figure 2-51). Initially, three phase-lock loops are on sweep (+) and the other three on sweep (-). At this time they are in an open-loop mode.

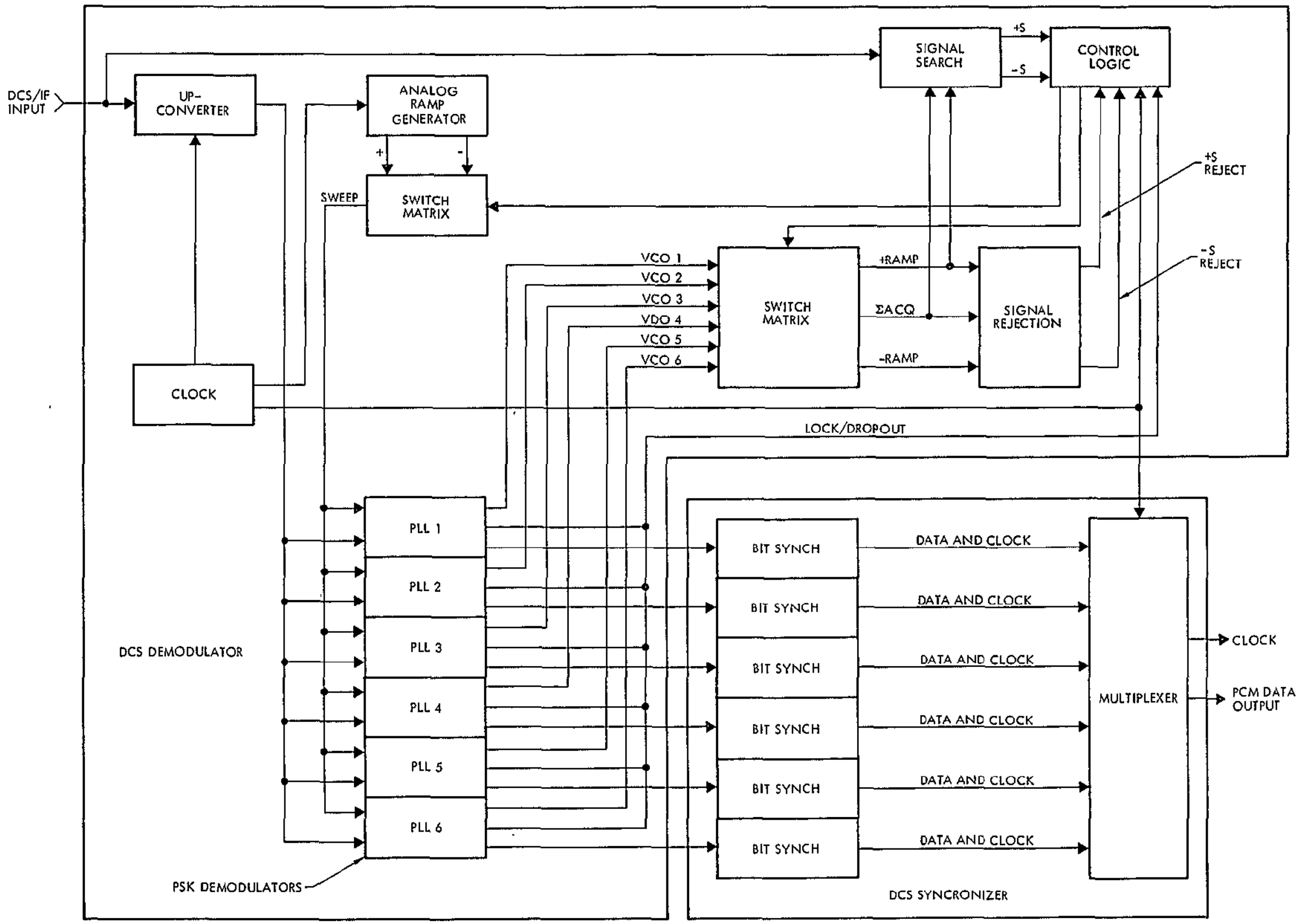


Figure 2-50

DEMODULATOR AND SYNCHRONIZER block diagram

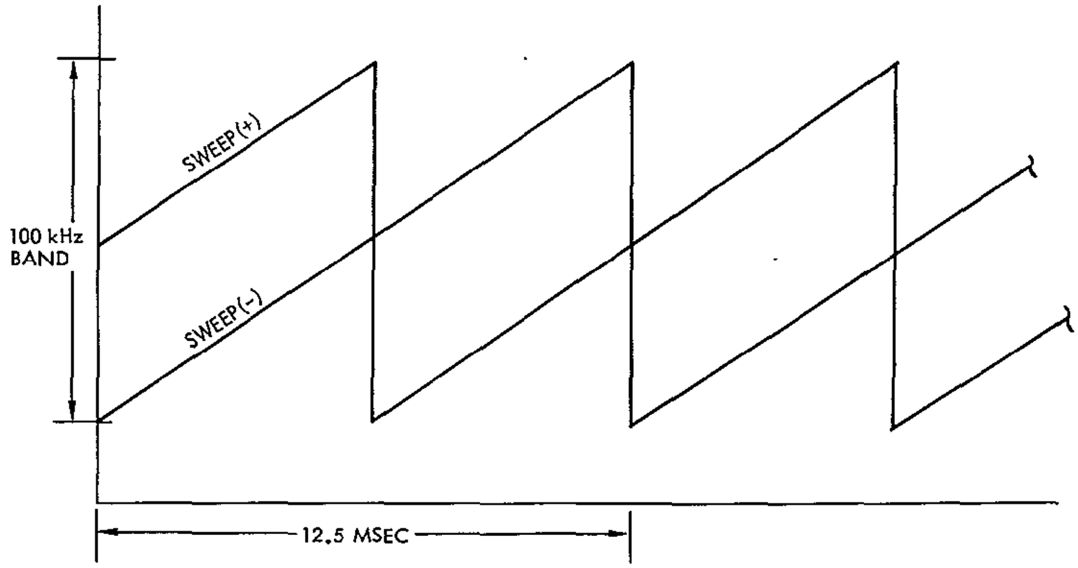


Figure 2-51
DCS DEMODULATOR SWEEP

When a carrier is located, a phase-lock loop is detached from its sweep at that frequency, and it then proceeds with demodulation.

Searching for carrier is performed by driving the VCO in one phase-lock loop with each sweep. The appearance of a signal is detected by circuitry which in turn drives logic to assign loops to carriers upon detection. If the first three carriers detected appear on one of the sweeps and so occupy the three loops on that sweep, then the logic "borrows" a loop from the other sweep to continue the process.

Outputs from the phase-lock loops are fed to 6-bit synchronizers. From each of these a pair of data and clock signals enter the multiplexer. Here they are word synchronized and serialized into one continuous data stream. Any gaps are filled with dummy messages to maintain continuity in the output.

The PCM decommutator accepts the PCM and clock from the DCS synchronizer and performs a conventional decommutation operation to present parallel data words to the computer. The messages appear at the decommutator as 87-bit groups consisting of five sync, 10 address, 64 data, and eight error code. The output rate is 9.6 kbits/sec.

The DCS demodulator drawer contains the acquisition circuits and phase-lock loops. The DCS synchronizer drawer contains the bit synchronizers and multiplexer.

2.7.5.1 DCS Demodulator

Acquisition Circuit

The acquisition circuit (Figure 2-52) continuously sweeps the 100 kHz baseband input and assigns a demodulator channel to each signal detected. Five channels may simultaneously demodulate input signals, which represents saturation of the demodulator subsystem.

The input spectrum is swept simultaneously with two separate frequency ramps to effectively double the sweep rate without increasing the sweep slope. The two sweeps are generated by two ramp generated such that the resultant frequencies of the two groups of phase-lock loops are separated by uniform coverage. Both sweeps have separate detection and rejection circuits which function independently. Each sweep covers the 100 kHz band in 12.5 msec (equal to the duration of preamble).

The ramp generator uses an 80 Hz clock to generate two sawtooth voltages. The period of both ramps is approximately 12.5 msec, and the (+) ramp leads the (-) ramp by one-half the sweep period. The voltage waveforms are generated by integrating a constant voltage and discharging the capacitors at the frequency and phase of the desired outputs. Operational amplifiers are used to produce linear ramps.

The assignment of channels to input signals is controlled by changing the mode of the I/Q phase-lock loop demodulator. Each phase-lock loop operates with its VCO in either the open- or closed-loop mode. In the open-loop mode the VCO is directly driven by a sawtooth voltage to effect the sweeping function. In the closed-loop mode the sawtooth voltage is removed and the VCO is driven from the feedback loop, causing the phase-lock loop to lock onto the signal nearest the VCO frequency. Each phase-lock loop receives up-converted baseband (382.2 kHz ± 50 kHz) so that the VCO tuning range ratio is less than 3:1. A larger ratio (lower up-conversion frequency) makes the VCO design unduly complex. Another consideration

for choosing the converter frequency is implementation. A final consideration is the clock system. If the up-converter oscillator is chosen properly, the digital clocks can be derived with simple counters. A choice of 307.2 kHz requires a modulo 32 counter for the 9.6 kHz.

For the detection process, the control logic selects two available phase-lock loops, one for each sweep (+R and -R). With both VCO's operating open-loop, two sawtooth voltages differing in phase by 180 degree sweep the VCO's from 332.2 to 432.2 kHz. The +R (0 degree ramp) and -R (180 degrees ramp) VCO outputs are then separately mixed with the predetection input, bandpassed, and amplitude-detected to produce the +S and -S outputs which indicate signal presence. The bandpass filter is centered on 307.2 kHz with a bandwidth of 2.5 kHz.

Once a signal has been detected, the appropriate VCO (+R or -R) is switched to the closed-loop mode. Since the frequency of the VCO is the same as the up-converted signal, the phase-lock loop VCO frequencies automatically phase closes to the detected signal and thus allow the phase-lock loop to acquire quickly. Each time a phase-lock loop is assigned to a signal, the control logic selects another available phase-lock loop to continue the sweep function. As an example of the method of detection, assume that a signal appears at 50 kHz. The phase-lock loops receive this signal at 50 + 307.2 = 357.2 kHz. When the +R sweep reaches 357.2 kHz, it produces a 307.2 kHz signal as it is mixed with the 50 kHz baseband. The filter passes the 307.2 kHz signal and an output occurs at +S. At the same time, the -R VCO is at 357.2 + 50 = 407.7 kHz since there is a 50 kHz difference between the two sweeps. When this frequency is mixed with 50 kHz, both sidebands occur outside the 307.2 kHz passband and not output appears at -S. In the same manner, when the -R sweep reaches 357.2 kHz, an output will appear at -S but not at +S.

Each time a +S or -S output occurs, it must be determined whether or not the signal has already been acquired. The signal detection/acquisition logic and the signal rejection circuit performs this test by comparing the input signal frequency with all the frequencies (Σ ACQ) of the phase-lock loops which are currently in lock. If an equivalent frequency is found, the S output is inhibited, otherwise a phase-lock loop is

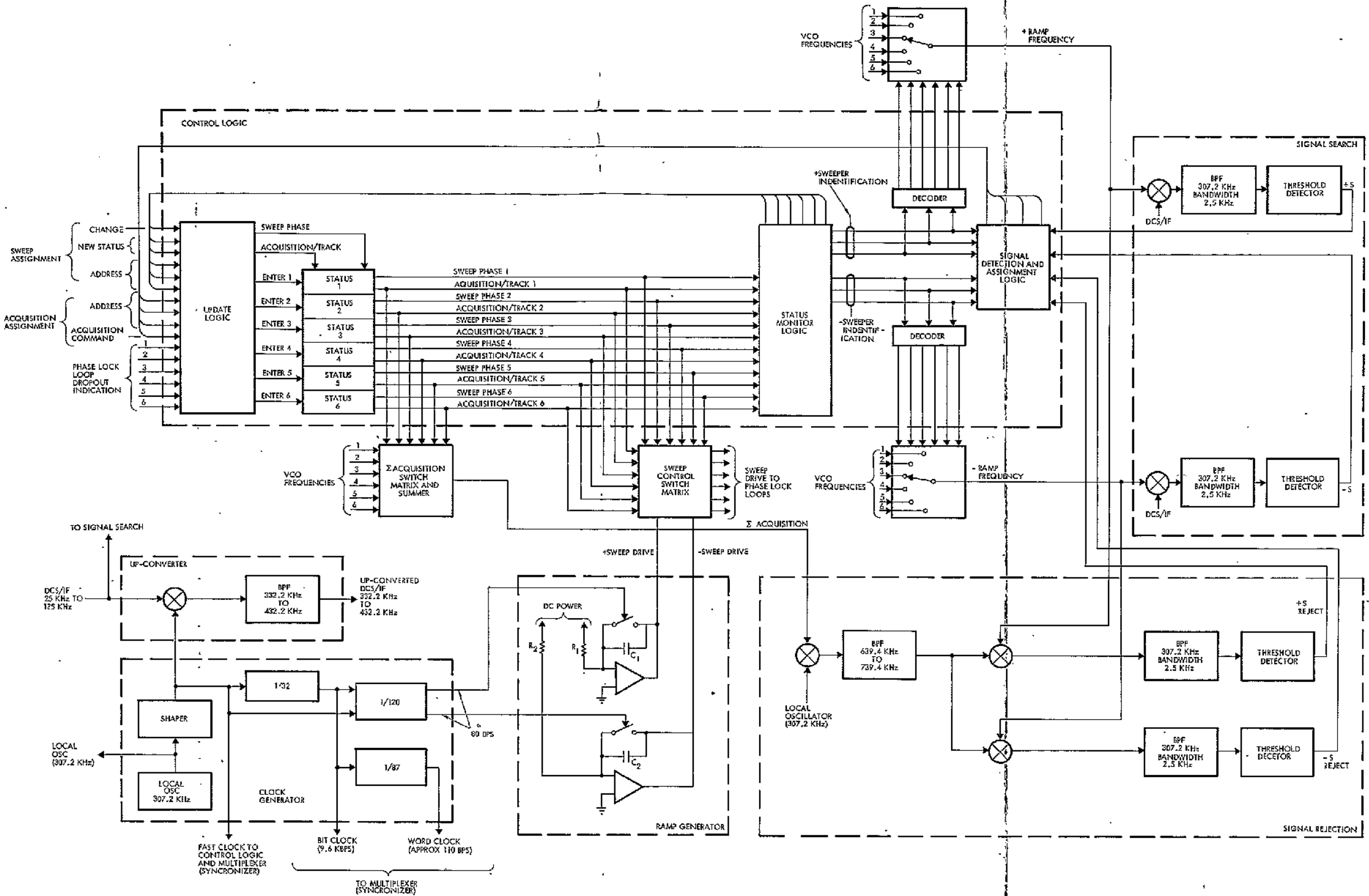


Figure 2-52
ACQUISITION CIRCUITS

FOLDOUT FRAME 1

FOLDOUT FRAME 2

PRECEDING PAGE BLANK NOT FILMED.

assigned to the signal. This test is made continuously by summing the outputs of the tracking VCO's, up-converting the sum, and then mixing the sum separately with the +R and -R frequencies. Each mixer output feeds a bandpass filter at 307.2 kHz and an amplitude detector to produce the -S reject and +S reject outputs.

The control logic monitors and controls the status of each phase-lock loop. Each time a new signal is detected, the (+) or (-) sweeping phase-lock loop is assigned to the signal and another phase-lock loop is assigned to the sweeping function. Analog switching is implemented in the switch matrices with FET driver-switches which are TTL compatible.

The signal detector and assignment logic receives from the status monitor logic two sets of 3 bits denoting the identities of the two phase-lock loops currently being used for sweeping. When a signal present indication (+S or -S) is received it is compared with the corresponding rejection signal (+S reject or -S reject). The outcome determines whether that carrier is to be captured or by-passed. If it is to be captured the appropriate 3 bits is gated together with an acquisition command to the up-date logic. Depending on the identity (address) represented by the 3 bits the up-date logic selects status circuit 1 through 6. This sets the two switch matrices to stop the sweep on that phase-lock loop, and to include the frequency of that phase-lock loop in the ΣAcq summation to the signal rejection circuit.

At the same time the output from the selected status circuit is fed to the status monitor logic as information as to which phase-lock loops are in the acquire mode and therefore not available for tracking.

The status monitor logic looks at the conditions of the phase-lock loops to obtain one that is not occupied with a carrier. Upon finding one not occupied the status monitor logic then feeds the update logic with: 1) a new identity (address) for a phase-lock loop to take over the signal search, 2) a new status consisting of sweep polarity and nonacquire (sweep) signals to operate the switch matrices via the new status circuit, and 3) a command to change status on that phase-lock loop.

The dropout signals from the six phase-lock loops provide the update logic with information as to the loss of lock that occurs at the end of a carrier. This is used for new assignments by the status monitor logic via the status circuits.

The performance of the acquisition circuit can be illustrated by referring to the detection circuit of one signal search channel. When a signal is present, the input to the bandpass filter will sweep over 100 kHz bandwidth. The bandpass filter will have an output only when the signal is within its passband. Using a bandpass filter with very sharp cutoff, the filter output appears as a pulse of RF carrier. The width of the pulse is a function of the bandwidth of the filter and the sweep rate (which is 100 kHz/25 bits), or 8 kHz per millisecond. The probability of detection increase with the bandwidth; conversely, false alarm rate decreases with the bandwidth. However, the matching of the VCO frequency with that of the incoming signal becomes poorer with a wider filter bandwidth and thus increases acquisition time. The exact tradeoff of these parameters has not been completed, but this can be illustrated by taking the bandwidth of the filter equal to 2.5 kHz. In this case, the pulse width

$$\frac{2.5 \text{ kHz}}{100 \text{ kHz}/25 \text{ bits}} = 0.3 \text{ ms approx.}$$

Depending on the signal-to-noise ratio and the setting of the threshold detector, the probability of detection and false alarm rate can be calculated in a similar manner to that for a pulse of carrier with a period of 0.3 ms. The maximum mismatch of VCO frequency and that of the incoming signal is 2.5 kHz. This mismatch, however, can be compensated by inserting a small offset to the VCO when it is disconnected from the sweep generator.

Demodulator

The PSK demodulator employs a conventional I-Q design which has been used before by TRW as shown in Figure 2-53.

Basically the I-Q demodulator consists of an inphase (I) channel and a quadrature (Q) channel. The I-channel performs the function of converting the modulated carrier into the baseband PCM signal and the Q-channel

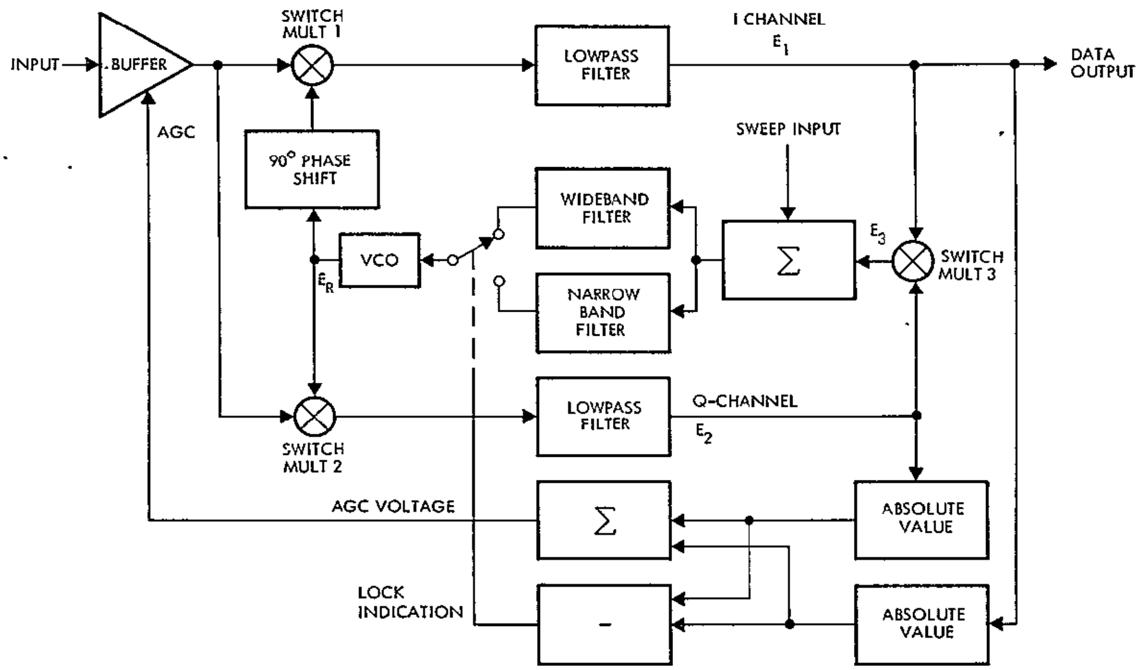


Figure 2-53
PSK DEMODULATOR

together with the output from the I-channel generates a phase error signal to drive the VCO into phase-lock with the incoming carrier. Mathematically, the operation of the I-Q loop demodulator can be described as follows:

$$\text{Input signal, } E_{IN} = A \sin [\omega_c t + \theta_i + {}_2\, \phi(t)]$$

where

ω_c = the carrier frequency

θ_i = the phase of the input-signal

$\phi(t)$ = the phase modulation and takes on the value of either +1 or -1

The VCO output, E_R, may be written as $\sin (\omega_c t + \theta_o)$ where θ_o is the phase of E_R. Then the outputs of the low pass filters will be:

$$E_1 = \frac{A}{2} \sin [\frac{\pi}{2} \phi(t) + \theta_i - \theta_o]$$

$$E_2 = \frac{A}{2} \cos [\frac{\pi}{2} \phi(t) + \theta_i - \theta_o]$$

The switching multiplier, SWB multiplies E_2 by +1 or -1 depending on whether E_1 is positive or negative. When the loop is in lock then $(\theta_i - \theta_o) \ll 1$, then. The output of the Q-loop is converted into a signal E_3 which is proportional only to the phase difference $\theta_o - \theta_i$, but not the data:

$\phi(t)$	E_1	E_2	E_3
+1	$\frac{A}{2} \cos(\theta_i - \theta_o)$	$\frac{A}{2} \sin(\theta_i - \theta_o)$	$+E_2 = \frac{A}{2} \sin(\theta_i - \theta_o)$
-1	$-\frac{A}{2} \cos(\theta_i - \theta_o)$	$-\frac{A}{2} \sin(\theta_i - \theta_o)$	$-E_2 = \frac{A}{2} \sin(\theta_i - \theta_o)$

Thus, the VCO control voltage is proportional to the phase difference (input phase - VCO phase) and will drive the VCO to a condition that minimizes this difference (at which time the loop is said to be "locked up"). When $\theta_i - \theta_o = 0$, $E_1 = A/2$ (t), which is the recovered modulation.

Indication of whether the loop is in a lock condition or not is gotten by subtracting the absolute magnitude of E_1 from the absolute magnitude of E_2 $(|E_1| - |E_2|)$. When the loop is not locked up, the signal energies in both the I-channel and Q-channel are about equal, so that $|E_1| - |E_2| \cong 0$. When the loop is locked up more energy will be in the I-channel so that $|E_1| - |E_2|$ will be some positive number. This lock indication is used to switch the loop filter, from wideband to narrowband when initial acquisition is made, or from narrowband to wideband when the loop loses lock (i. e. when the input signal vanishes).

The loop gain of the PSK demodulator (and therefore the loop bandwidth, acquisition time, and other parameters) is proportional to input signal amplitude. To minimize all of the variations, an AGC circuit is included to keep the input to the loop at a constant amplitude. The AGC control voltage is derived by summing the signal energy in the I and Q channels.

The demodulator is essentially a carrier tracking loop. The parameter of the loop will be selected to meet the transient response requirements of completing acquisition in 11 bits by means of a switchable bandwidth, wideband for acquisition, and narrowband for operation. The operating bandwidth depends mainly on the signal-to-noise ratio. However, the acquisition bandwidth is determined by how close the VCO frequency is set to the signal frequency by the acquisition circuit. Preliminary analysis indicates these bandwidths are achievable.

2.7.5.2 DCS Synchronizers

Bit Synchronizers

The bit synchronizer employs the I-Q design which has been used before by TRW. It is essentially a simplified version of the unit previously developed. A block diagram of the bit synchronizer is shown in Figure 2-54.

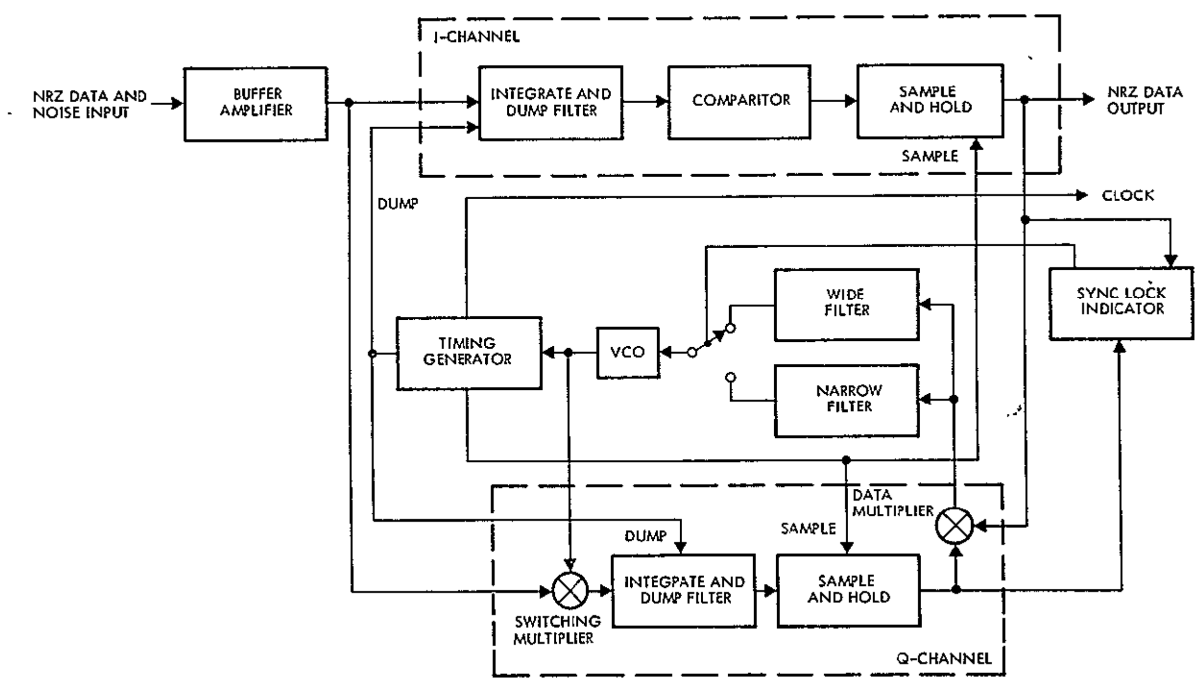


Figure 2-54
BIT SYNCHRONIZER

The function of the bit synchronizer is to optimally detect and reconstruct the PCM data in presence of noise and to estimate the bit phase. For NRZ data, the optimal detector is an integrate-and-dump

filter which integrates the input over a bit time; the resultant of these sampled and dumped. The integration-and-dump function as shown in Figure 2-46 is performed in the I-channel which has, in addition, a comparator and a sample-and-hold circuit.

For bit synchronization, a phase-locked loop is used. The phase error is provided by the Q-channel in conjunction with the I-channel. The Q-channel is composed of 1) a switching multiplier, 2) an integrate-and-dump filter, 3) a sample-and-hold, and 4) a data multiplier. The switching multiplier, integrate-and-dump, and sample-and-hold circuits provide a sampled-and-held representation of the phase error between the incoming bit clock component and the phase of the Q-channel. The data multiplier, which simply switches the polarity of the analog signal in accordance with the output of the I-channel at the occurrence of the sample pulse, provides sense information to the VCO through the loop filter as to drive the VCO in the proper direction to achieve lock. Thus, the VCO output is phase locked to the bit rate clock. The timing for the integration-and-dump circuits as well as sampling is derived from the VCO and is created by the timing generator.

As in any phase-lock loop, the loop parameters have to meet its transient and steady-stage response. Design calculations for phase-lock loop are well known. The bit synchronizer is designed to meet the following operating specifications:

Bit rate: 2.048 kbits/sec ± 2 percent

Acquisition time: in 12 bits with 100 percent transistions

BER: less than 5×10^{-5}

As an aid to trouble shooting, a synchronizer-in-lock indication is also provided by taking the difference of the amplitude (absolute value) of the I-channel and Q-channel output. When the bit synchronizer is in lock, the I-channel amplitude will be much higher than that of the Q-channel; otherwise their amplitude will be equal.

Multiplexer

The multiplexer (Figure 2-55) receives data and clock from each of the 6 bit synchronizers and generates a single output of multiplexed data

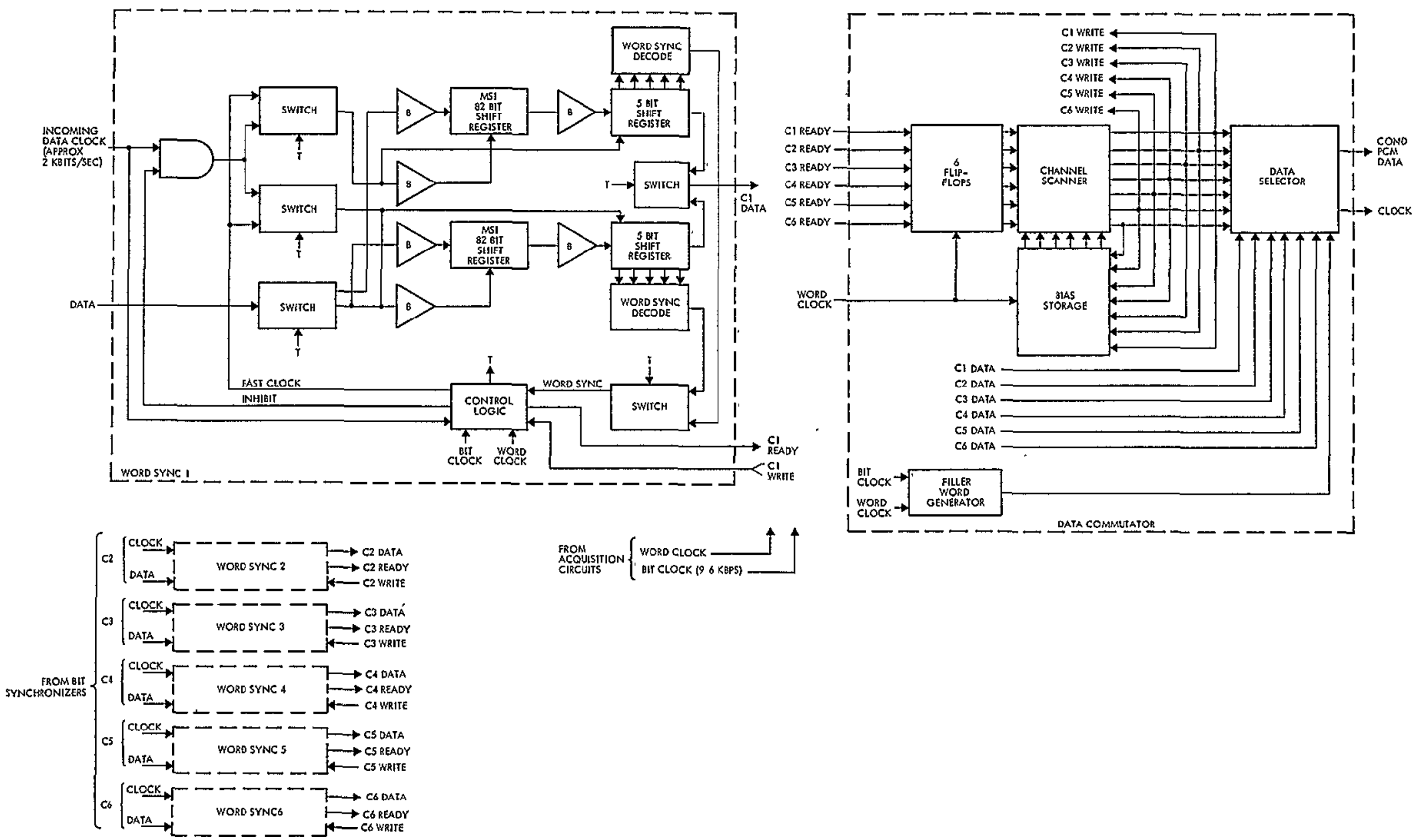


Figure 2-55

MULTIPLEXER

words. Since only five channels are allowed to track simultaneously, the maximum input rate is 5 x 2.048 kbits/sec = 10.24 kbits/sec = 93.1 words/sec (110-bit word). The output rate is 9.6 kbits/sec = 110.4 words/sec (87-bit word) and since the output word rate is greater than the input word rate, overflow does not occur. The output word length is flexible and can be extended to 103 bits with no additional storage. For word lengths up to 110 bits, a probability of overflow is small even if no additional storage is used.

The multiplexer consists of six word synchronizers and a data commutator. Each word synchronizer must shift data in with the data clock, hold the word, and then serially shift the word out with the bit clock. Two registers are required since the next input word might appear before the stored word is shifted out. The usual implementation for shift registers is to use a serial-in, parallel-out register, with a parallel-in, serial-out register. The disadvantage of this method if the 110-wire interface needed to parallel transfer a word from the first register to the second. A significant saving is made by using two serial-in, serial-out shift registers, thus eliminating 81 connections between registers for each channel. This alternative method performs the same function with only a slight increase in logic (one extra word sync decoder per channel). The use of a serial shift register has the additional advantage of allowing MOS-MSI implementation.

The diagram shows the use of the two serial-in, serial-out shift registers in the word synchronizer. As data appears on the channel, it is clocked into one of the registers with the data clock from the bit synchronizer. When the word sync pattern is decoded, the data clock is inhibited, the first 5 bits are preset to the output pattern and the ready line is set. In addition, the two registers are functionally interchanged, i.e., the loaded register becomes the output register, and the other register is prepared to accept the next input stream. When a signal is received on the write line, the bit clock is gated to the loaded output register, shifting the data word through the commutator to the output. The ready and write signals are cleared after the last bit and the cycle continues with each register serving alternatively as an input and output register. During the

multiplexing process, the data commutator requests data from appropriate word synchronizers by means of the write signals. At the beginning of each output word slot, the ready lines are sampled. On the basis of the last-serviced channel, the scanner selects the data channel to be serviced next. Once the next channel has been chosen, the appropriate write signal is activated, and that data channel is switched to the output. The bit clock is used to shift data out, while the word clock is used to mark output word slots. These two clocks provide automatic synchronization between the word synchronizers and data commutator.

The channel scanner is a fast (combinational) line scanner which selects the next channel to be serviced as a function of the last channel selected and the channels requiring service. The bias storage retains the number of the last channel used and is updated after each output word. This bias number is used by the scanner as a starting point. In effect, each channel is sampled in numerical order beginning with 1 + bias number) and ending with the bias number, using a circular assignment of numbers. The scanner selects the first ready channel found. This method of scanning is nonpreferential and ensures that each channel receives equal attention. If no channels are ready during the scanning process, the filler line is selected. This line gates a simple pattern to the output to maintain bit and word synchronization at the receiving end during gaps in data. The data selector is a simple gating array which serves as a one-of-seven switch.

2.7.5.3 DCS IF Simulator

The purpose of the DCS IF simulator (Figures 2-56 and 2-57) is to accept the output of the stored program PCM simulator and produce from it a test signal that will simulate a representative data input to the demodulator/synchronizer for verification of the DCS data processing function. This signal verifies the ability to extract data from five simultaneous messages on different frequencies as well as from messages arriving at different frequencies and different times. There is no requirement to develop the true randomness of the signal normally received from DCS platforms.

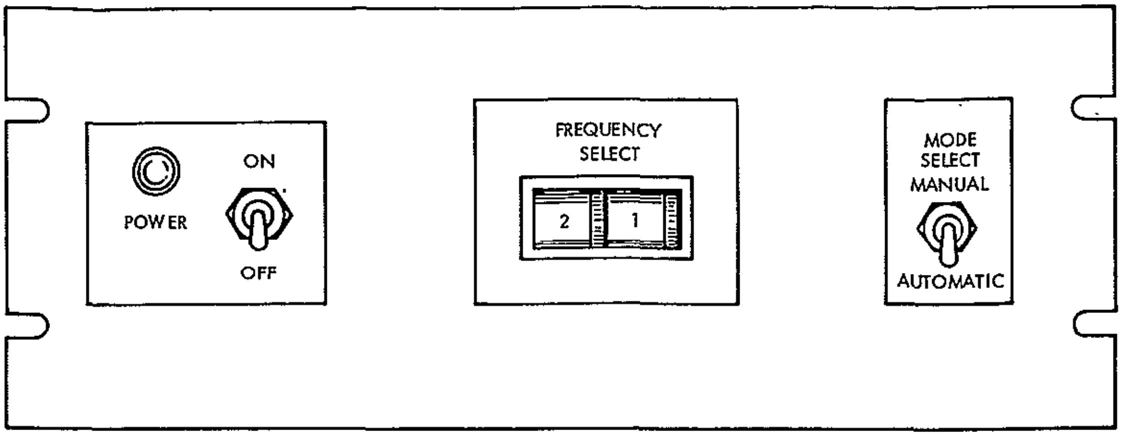


Figure 2-56

DCS IF SIMULATOR FRONT PANEL

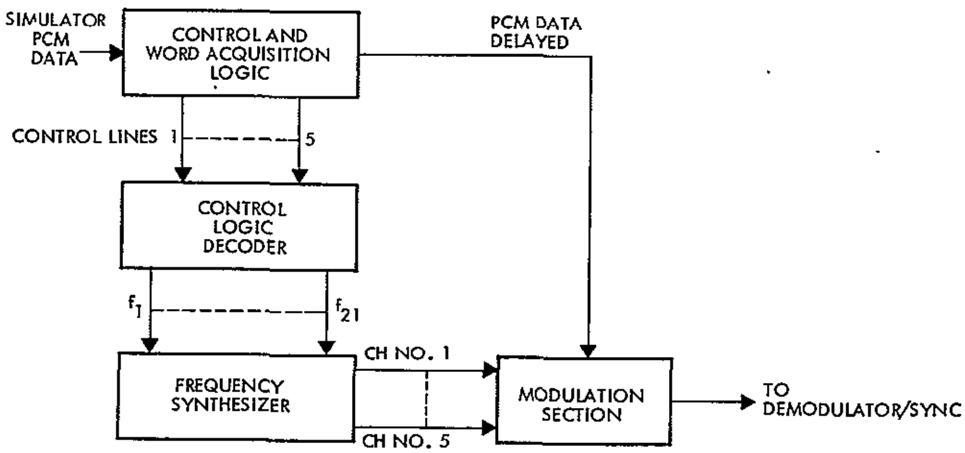


Figure 2-57

DCS IF SIMULATOR flow diagram

Either automatic or manual mode may be selected by the mode select switch on the front panel.

In the automatic mode all output signal frequencies are controlled by the input data program from the PCM simulator and requires no operator intervention. In this mode, output signals may be any one of 21 single frequencies or one of 4 specific groups of five of these frequencies simultaneously.

The manual mode is used primarily for fault isolation testing. In this mode, the output signal is a single frequency, independent of the input data program, which is selected by the frequency select switch on the front panel.

3. NASA Data Handling Facility

CONTENTS

3. NASA DATA PROCESSING FACILITY

The function of the NASA data processing facility (NDPF) is to convert video data produced by the return beam vidicon (RBV) and the multispectral scanner (MSS) into photographic imagery, to process all related housekeeping telemetry and orbital data, to remove radiometric and geometric errors in selected images, to geographically index and catalog data about the imagery, and to provide imagery (film and montages) and data including DCS to users in both a standard bulk mode and in response to special requests.

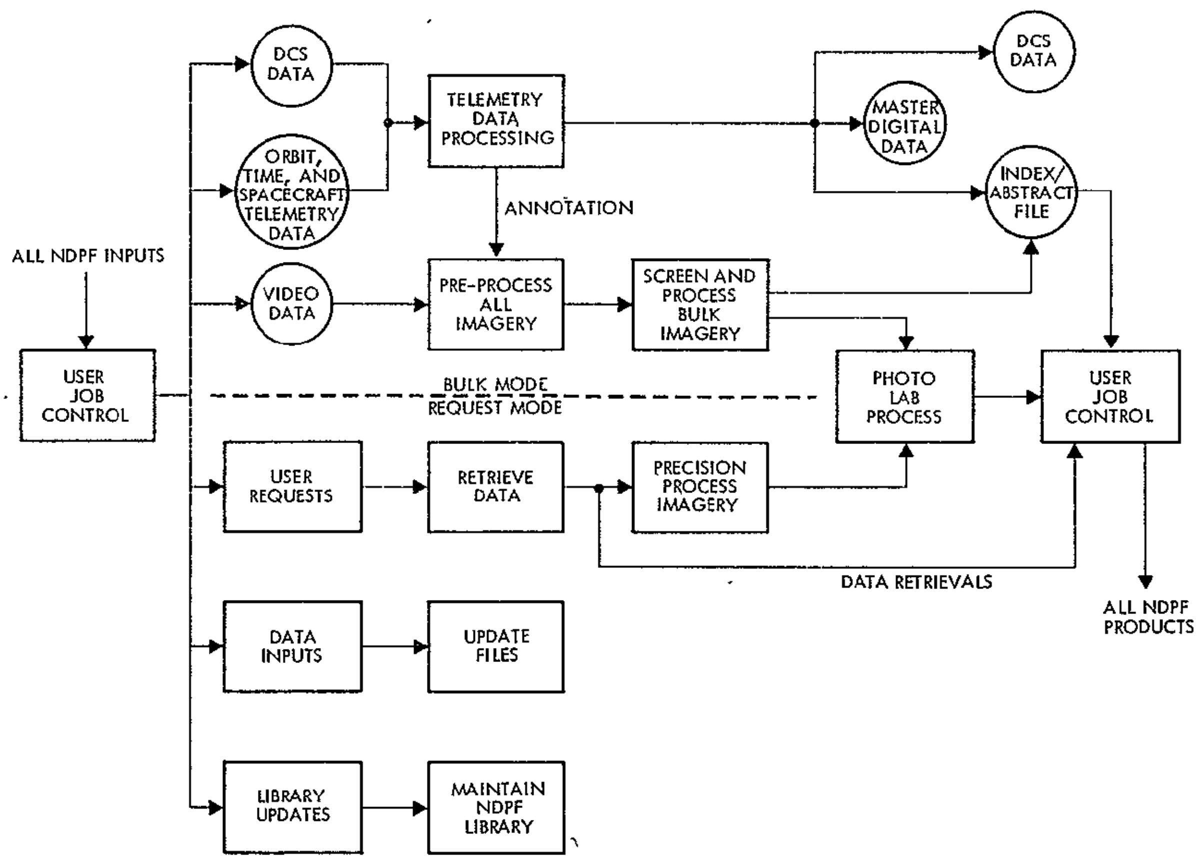


Figure 3-1
GENERAL NDPF DATA FLOW

A general data flow diagram is shown in Figure 3-1. The procedural operations within the NDPF have been broadly discussed in Section 1.3 of this volume. Unlike the OCC, the NDPF is primarily a batch process production facility with sufficient flexibility to permit

priority and special handling requests to be accommodated. Physically, the NDPF consists primarily of specialized electronic and photo-optical equipment for generation of photographic images from sensor data tapes and photo laboratory equipment for processing the film products. The operations within the NDPF depend significantly upon the support of a powerful digital computer, a comprehensive information management system, and the features provided by the GDHS unified display system (see Section 4 of this volume).

3.1 IMAGE PROCESSING

The principal function of image processing is to convert the video data produced by the RBV's and the MSS into photographic imagery and into computer readable data tapes. The video data, as received, will depart from an accurate representation of the imaged ground scenes by both geometric and radiometric errors resulting from atmospheric effects, sensor characteristics, spacecraft attitude variations, transmission links, and recording devices. Image processing is required to reduce these errors to acceptable levels.

Three major constraints exist which limit the extent to which the errors can be removed:

- Amount of information available to quantify the errors
- State-of-the-art limits on the accuracy of processing and reproducing devices
- Time and expense involved in the design of a cost-effective system.

The last constraint has led to the concept of providing degrees of image processing from minimum corrections of 100 percent of the received data (bulk 1); through moderately good corrections on a major fraction of the data (bulk 11), or to all of the data; to more sophisticated processing of a relatively small fraction of data (precision modes 1 and 11). Table 3-1 summarizes the image processing modes and the types of operations performed within each.

Two types of image processing are employed: digital and photo-optical. Digital processing is utilized for precision image corrections

Table 3-1. Image Processing

	Geometric Corrections	Photometric Corrections	Radiometric Corrections	Mechanization
Bulk Modes (Operations on all Input Imagery)				
Mode I	Correction for earth rotation effect on MSS images	1) Shading 2) Channel gain derived from transmitted calibration signals	None	Preparation of high-density tapes followed by off-line laser beam recorder reproduction
Mode II	1) Reseau and keystone correction of RBV images 2) Correction of MSS images using attitude date 3) Projection into UTM coordinates 4) Projection to average altitude non-sea level datum (datum used identified in annotation text)	Same as Mode I	None	1) Computer detection of RBV reseau points 2) Computer calculation of synthetic MSS reseau based on attitude data 3) Precision photo restitutor processing under computer control
Precision Modes (Operations on 5 percent or less of Input Imagery				
Mode I	1) Reseau correction of RBV images 2) MSS processing by use of refined attitude data and verified ephemeris 3) Image transformation into UTM or oblique Mercator (user's choice) 4) Projection to average altitude non-sea level datum (datum used identified in annotation text)	1) Shading 2) Channel gain derived from transmitted calibration signals	None	1) Digital computer processing 2) Image production by laser beam recorder 3) Use of ground truth where feasible 4) MSS yaw angle refinement by correlation with one like-spectral RBV channel. Error in yaw estimate merged with other attitude data in computer processing 5) Production of corrected digital tapes
Mode II (NASA option)	Same as Mode I with choice of one or more of the following 1) RBV blemish removal 2) IMC where possible 3) Image transformations into specified grids 4) Image enhancement 5) MTF correction 6) Structured noise removal 7) Reseau removal with cosmetic fill-in 8) Radiometric adjustment for atmospheric effects 9) Nonstandard composite color balance			

and bulk processing by photo-optical methods is under computer control. In addition, special processes are available, such as reseau removal, modulation transfer function compensation, and coherent noise removal,

all implemented by means of the digital computer and an increased software repertoire.

The data services laboratory provides those functions necessary to support image production and dissemination. These functions include processing quality control, production control, system scheduling, accounting, data storage and retrieval, as well as user liaison (e.g., receiving requests and shipping products). The laboratory provides the overall information management for the NDPF.

3.1.1 Tape-to-Film Image Recording

Video signals in storage on magnetic tape are converted to film images in a laser beam recorder. An investigation of the characteristics of several types of devices, including conventional cathode-ray tube recorders, noncoherent light recorders, electron beam recorders, and laser beam recorders, clearly indicates the superiority of the latter for use in the NDPF (see Volume 17, Section 2.8). The laser beam recorder uses precision mechanical drives for scanning and film advance. The video data are buffered and synchronized to the recorder, rather than synchronizing the recorder to the data as is done in electronic scan devices. A special-purpose controller operated off-line with data generated by the NDPF computer provides the necessary data synchronization.

A single type of laser beam recorder is used for both the RBV and MSS sensor data. All images are first generated by the laser beam recorder. In bulk processing modes the laser beam recorder produces film images of sensor coverage with little or no corrections, whereas precision mode computer-generated compensations permit fully-corrected images to be recorded by the laser beam recorder. As will be described later, uncorrected bulk mode laser beam recorder images are photo-optically processed to obtain a moderate degree of correction on all output (bulk II).

Error sources for the laser beam recorder can be summarized as two primary types, geometric and photometric errors, and expressed in terms of four key parameters as follows:

Longitudinal error	}	Geometric
Scan coordinate error		
Gamma correction error	}	Photometric
Grey-scale error		

Combined error estimates obtained for each laser beam recorder type showed that the differences in the estimates were relatively minor, with the following figures being representative:

- Geometric error: 0.05 percent
- Photometric error: 3.1 percent
- Position error on ground: 328 feet

Included in the above figures are the estimates for the preparation of the input signals, such as digital-to-analog conversion and the required multiplex switching.

The laser beam recorder produces high-resolution film imagery using a precisely-formed laser beam horizontally deflected by a high-inertia mechanism and intensity modulated by data supplied from high-density digital tapes. The laser beam recorder includes an integral roll film transport for vertical movement of the film and a block annotation device for placing alphanumeric annotation on the imagery.

The laser beam recorder accepts digital 7-bit image samples at 2.02 M samples per second and converts the data to a continuous analog video stream which modulates the intensity of the laser beam as it exposes the film. The laser beam recorder provides a very stable line scan rate of 400 lines per second outputting a 250 nanosecond pulse at the beginning of each line to phase the outputting of data samples from the tape-to-film control unit. Each 9-inch line of data is composed of 5060 discrete resolution cells to provide the actual image plus tick marks, a gray scale, and an area to be block annotated. The laser beam recorder automatically recalibrates itself after each line.

The laser beam recorder provides a constant spot-width commensurate with the requirement to resolve 5060 elements in a 9-inch line, while

the vertical dimension can be adjusted to compensate for the differences in MSS and RBV line structure. The vertical image dimension of 7.2 inches must then be covered by either number of lines; therefore, the spot size is increased or decreased upon command from the tape-to-film control unit as the type of imaging being reproduced changes.

The film transport moves the roll film to provide vertical displacement of the laser beam along the image in synchronism with the line scan rate. The film transport moves the film at the rate required to provide a contiguous image of equal geometric scale for either MSS or RBV data. The rate of motion is increased in conjunction with laser spot height increase for MSS imagery which has the lower number of lines. A rapid film advance feature provides unsynchronized film motion at four times the fastest synchronized advance rate.

External calibration in the form of digital sample values can be input at a maximum of 2.02 M samples per second to the laser beam recorder providing multiplicative corrections to the image data. For operation with bulk RBV images, the laser beam recorder accepts digital values representing shading correction factors, converts the digital data to an analog video data stream, and applies the video data to circuitry which adjusts the amplitude of the analog image data and subsequently the laser intensity.

The laser beam recorder accepts and buffers 400 alphanumeric character codes for flashing block annotation data on the imagery. The 6-bit character codes are provided by the tape-to-film control unit in a predetermined order at 1000 characters per second. The codes are stored and decoded to drive appropriate segments of character generation equipment when the tape-to-film control unit commands the flashing of the annotation.

3.1.2 Output Format and Image Annotation

The basic format for annotated ERTS imagery, both RBV and MSS, is shown in Figure 3-2. The image is recorded on 9.5-inch film at a scale of 1:1,000,000, thus occupying a square 7.296 inches on a side. The entire format, including geographic tick marks, grey scales,

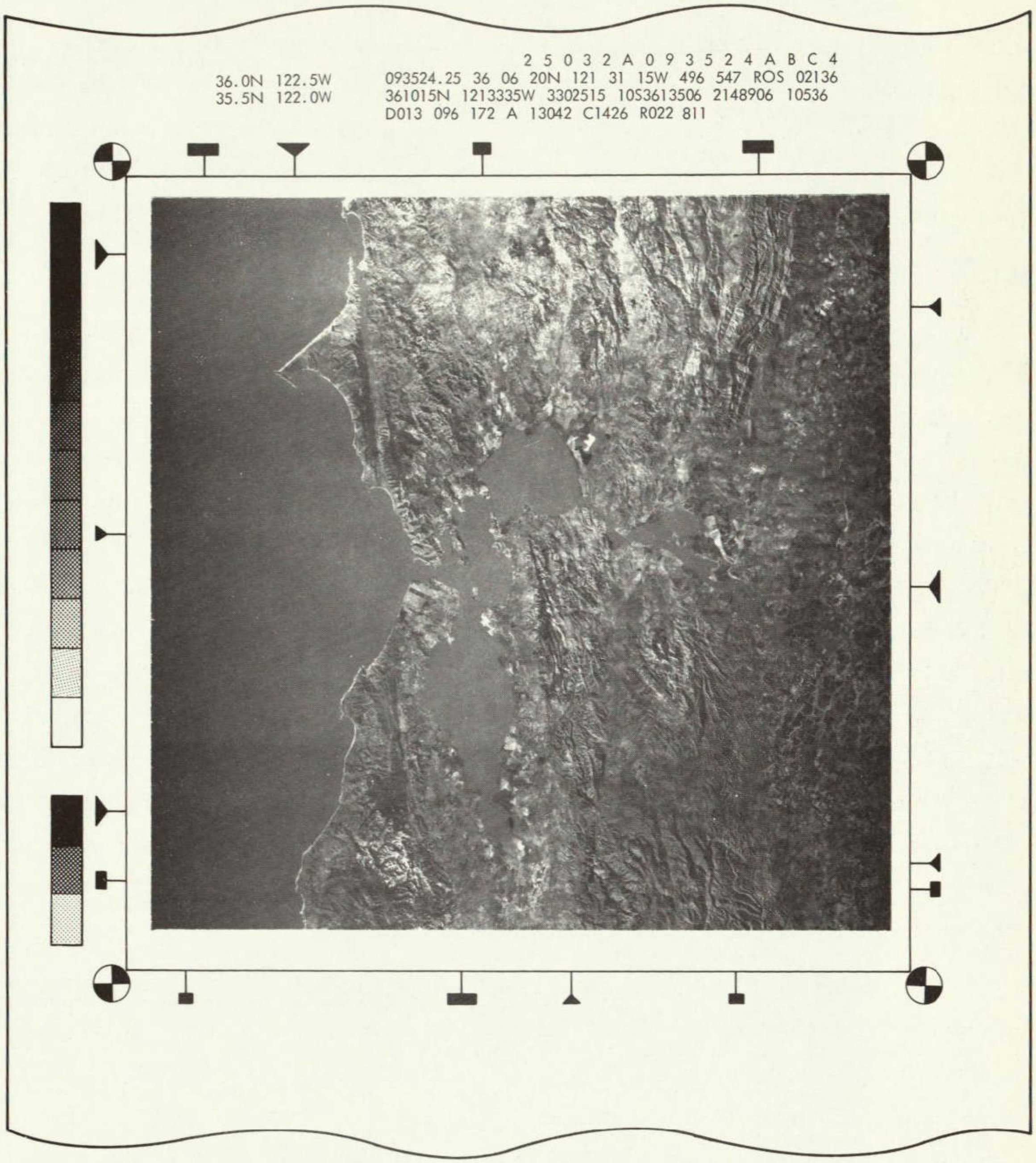


Figure 3-2
FRAME AND ANNOTATION FORMAT

registration marks, and annotation text lies within an area 8.5 inches wide and under 9 inches long to conform to conventional film formats; it could be increased to accommodate new requirements.

The imagery itself, the geographic tick marks, the grey scales, and the registration fiducials are applied in the laser beam recorder,

since they depend on the photometric or dimensional characteristics of the instrument. The alphanumeric annotation is exposed by a cathode-ray tube in a block above the imagery. The cathode-ray tube annotation station is attached to and is an integral part of the recording device, to facilitate metering of the film to the proper location for annotation.

3.1.2.1 Geographic Tick Marks

Each tick mark consists of a shaft 0.1-inch long and 0.0035-inch wide, with an identifying head, bringing the total length to 0.2 inch. The identifying shapes distinguish between latitude and longtitude marks and between even degree and half-degree positions. The inner end of each shaft intersects a square 7.7 inches on a side, delineated by lines 0.0035-inch wide. This intersection is the point at which the location is to be taken. The 7.7-inch square defines an area within which the image will always be contained. Orbit parameters and earth oblateness together can cause the image scale to vary by as much as 3 percent; this could cause the picture to be 0.22 inches larger than nominal when presented at 1:1,000,000 scale. In addition, yaw attitude can produce a skew in MSS imagery which when corrected could require 0.10 more room in the cross-track direction. Thus the area dedicated to the image should be about 0.32 oversize, for a total of 7.62 inches on a side. The 7.7-inch square provides a slight safety factor over this.

The geographic values associated with the tick marks are given in the two left-hand columns of the annotation text. In Figure 3-2, latitude marks are indicated by triangles, longitude marks by rectangles, and the legend is translated as follows: "The lowest latitude mark on the left side is 36°N; the lowest latitude mark on the right side is 35.5°N. The leftmost longitude mark on the top is 122°W."

3.1.2.2 Registration Fiducials

The registration marks are circles 0.3-inch in diameter with internal crosses centered at the corners on an 8-inch square. Since they are put on the format with the imagery they can be used to register different spectral channels. The shape facilitates either manual or machine registration.

3.1.2.3 Sensitometric Strips

The sensitometric strips are 0.3-inch wide along the left-hand edge of the format longitudinally within the image region and separated by 0.1-inch from the tick marks. Space is reserved for in-flight photometric calibration data, but the form cannot yet be established. The longer strip, to calibrate the laser beam recorder performance, contains 11 steps having an interstep ratio of $\sqrt{2}$.

3.1.2.4 Identification Number

The identification number, of 14 to 16 characters, provides a unique frame identification, including level of processing, which is easily read by the operator. The first five digits give the date in day, month, and last digit of the year. Next is a letter designating the satellite, then the time (GMT) in hours, minutes, and seconds. One letter A through H denotes the spectral channel. For color composites three letters are used, A, B, and C for RBV composites, and three of D through H for MSS composites. The last number indicates the processing level achieved. Identification characters are 0.2-inch high.

3.1.2.5 Annotation Text

The remaining annotation is in alphanumeric characters 0.1-inch high, arranged for easy identification of meaning without unnecessary text. In Figure 3-2, alphanumeric text (exclusive of geographic notation, already described) gives, in the first line:

- Picture time to the nearest 0.01 second
- Subsatellite point in geographic coordinates
- Spacecraft altitude
- Sun angle
- Receiving station
- Orbit number.

The second line shows:

- Picture center in geographic coordinates
- Heading

- UTM designation of picture center
- Deviation of UTM grid from meridians.

The third line includes:

- DCS data available for the image area
- Satellite designation
- Date of processing
- Cloud cover in tenths by quadrants
- A group reserved for coded remarks.

3.1.3 Image Processing Approach

Geometric and photometric image processing are undertaken in the NDPF. Both involve two aspects. The first concerns establishing a quantitative representation of the corrections to be made and the second involves the application of these corrections to the uncorrected image data to obtain the desired output.

Geometric errors arise in the RBV's due to imperfect scanning of the target by the electron beam. A 9 x 9 array of reseau marks etched on the inner face of each RBV capture the essential nature of these scanning distortions for ground extraction. Since the true position on the RBV faceplate of each reseau mark is known, or through orbit and attitude knowledge its projected position on the earth is established, a correction function can be developed conveying the magnitude and direction each image point should move to eliminate distortions. Geometric errors arise in the MSS imagery primarily due to spacecraft attitude variations. Thus the correction function required is derived from telemetered attitude data generated by the attitude determination system (see Volume 2). The technique for modeling the correction function is through a set of artificial reseau points. Hence geometric correction can be implemented for both the RBV and the MSS images in an identical manner.

Radiometric errors also arise in each imaging system and are substantially more difficult to deal with. The radiometric accuracy is

influenced by the resolution of both the RBV and MSS system, the signal-to-noise degradation, and the effects of atmospheric transmission and backscatter. The performance and limiting resolution of both the observatory sensors depend on the target luminance and contrast, the system signal-to-noise ratio, and the system modulation transfer function. The sensors receive light which has passed twice through the atmosphere after reflecting from the target, as well as light which has backscattered from the atmosphere or has multiply-scattered after reflecting from terrain adjacent to the target. The relative strength of the two returns is about equal for target reflectance of 10 percent (typical target), with the target irradiance dominating for greater reflectances. The atmospheric return may vary by as much as a factor of two, thus precluding constant corrections for removal of its effects. Faceplate quantum efficiency variations, shading and gamma effects, on the other hand, are amenable to removal when properly characterized.

3.1.4 Bulk Processing

Bulk processing has been structured for both a minimum correction mode (bulk I) and a mode providing as much correction as can be reasonably accomplished on a routine basis without excessive system size (bulk II). It will be seen that bulk I processing is contained as an initial step in the bulk II mode. Consequently, it is possible to reduce bulk II processing by applying a cloud cover and quality screening criterion. However, the system is configured to accommodate bulk II operations for a full Case B load.

A simplified diagram illustrating image processing operations appears in Figure 3-3.

3.1.4.1 RBV Bulk Processing

The minimum-correction bulk processing (bulk I) of RBV imagery consists of producing images by means of the laser beam recorder with no geometric or radiometric corrections. Photometric corrections are made by using transmitted calibration data for individual camera overall responsivities and shading for known RBV camera effects, if required. The recording will always be from a video tape, permitting prior

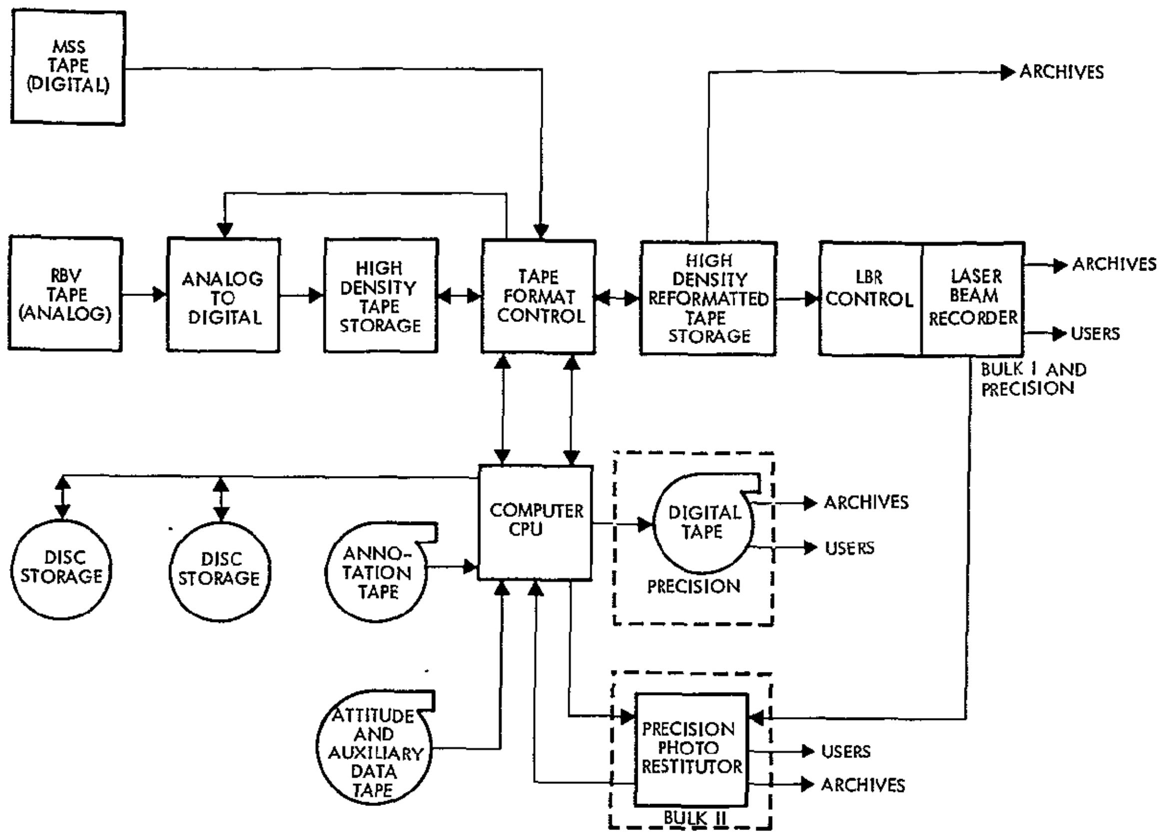


Figure 3-3
GDHS IMAGE PROCESSING SYSTEM simplified block diagram

computation of annotation data and making operation slower than the real-time recording rate possible. This approach facilitates the design of a formatter-buffer to synchronize the data to the recorder and to merge sensitometric strips and geographic tick marks with the picture data. The laser beam recorder operates at 400 lines per second, producing a frame of RBV imagery, including the geographic marks and the grey scale, in about 13 seconds.

The alphanumeric annotation material is exposed on the frame from a cathode-ray tube station which is an integral part of the laser beam recorder. The annotation data are obtained from a tape prepared in advance by the computer. The three RBV spectral channels exposed at the same time appear sequentially on the output roll film. After exposure at the laser beam recorder-cathode-ray tube recording and annotation

station, the film is moved to the photo laboratory for processing and duplication for distribution to the users (if required).

Bulk processing which provides the greatest degree of correction consistent with processing of all imagery in a reasonably sized facility (bulk II), makes use of an electronic-optical device called the precision photo restitutor. Inputs to the precision photo restitutor consist of an image generated by the laser beam recorder along with control instructions generated by the computer. The precision photo restitutor scans a small segment of the image. A small central slit of the segment is then printed on raw film stock through the optical system. The scanned segments are then moved slightly at right angles to the printing slit and the process is repeated. In actual operation, this is a continuous process; the rate of travel perpendicular to the printing slit is slow enough so that the servo-mechanisms driving the correcting optics can keep the error signals negligibly small, and the illumination of the image is properly adjusted so that the effective exposure is that desired. After a strip covering the length of the image has been exposed, the device moves precisely to the next adjacent strip and the process is repeated.

The input image prepared by the laser beam recorder is the master produced in the bulk I mode. For bulk II processing, corrections for both internal distortions indicated by reseau measurements and keystoning arising from departure of the camera line-of-sight from the nadir are incorporated into the coordinate transformation and determined using the computer.

In the precision photo restitutor the actual printing is done optically. With the input resolution no better than 11 line pairs per millimeter (from the camera scan pattern recorded at 1:1, 000, 000 scale) the optical system will introduce negligible degradation of the resolution. Although the corrections in each printing slit are no higher than linear, the small size of the slit makes the overall correction an excellent piecewise linear approximation to much higher order correction. The image area is divided into nine strips. While the boundaries of these strips may be observable under magnification because of very slight but inevitable

mechanical alignment errors, the image error introduced thereby is less than the resolution of the system.

In the bulk II mode, RBV reseaux for all images are measured in the computer and coordinate transformations are obtained using this information including keystoning corrections and projection to UTM using attitude and position data. Correction to an average altitude non-sea level datum is made for all imagery and the datum used is given in the annotation text.

All images are separately corrected in the precision photo restitutor, operating under computer control. Composite color images are produced in the precision photo restitutor in the same mode. Annotation is updated to relocate tick marks to conform to the corrections applied and to UTM designations, and the text provides a new identification number, cloud cover data, and correction of picture center if required.

In bulk II processing, RBV images prepared on the laser beam recorder (bulk I mode) are examined at a screening station for cloud cover and gross instrumental malfunctions, then moved to the precision photo restitutor for further processing. The geographic tick marks from bulk I processing are replaced to reflect changes required by the geometric corrections, and the identification number is changed to indicate the new level of processing. The precision photo restitutor also has an associated cathode-ray tube annotation station permitting any other required changes, such as corrected picture center and addition of cloud cover data.

The exposed but unprocessed images from the precision photo restitutor are photo-processed and duplicated for distribution. Color composites are made using the registration marks to obtain good registration. It is also possible to make color composites on the precision photo restitutor by successive printing of the three RBV images through appropriate filters on a single-color film. This method will also be scheduled to obtain full utilization from the precision photo restitutor.

3.1.4.2 MSS Bulk Processing

The minimum correction (bulk I) processing of MSS imagery is substantially the same as that for RBV image data. Reading the parallel

channel MSS tapes onto the single-channel laser beam recorder requires some special handling. The MSS data is recorded in 100 nautical mile sections covering approximately the same area as the corresponding RBV frames. The sections are chosen so that their midpoints (in time) correspond to the RBV exposure time and their lengths are 100 nautical miles at the nominal speed of the subsatellite point on the ground. Thus the coverage differs from that of the RBV frames only to the extent of spacecraft attitude and position changes from nominal. Since each new set is centered on the corresponding RBV set, there is also the required 10 percent overlap between successive frames.

The four (or five) spectral channels are recorded sequentially on the 9.5-inch roll film. A special formatter-buffer (see Section 3.7.4) selects the appropriate six channels representing six lines of one spectral band, and prepares a high-density tape which is formatted for laser beam recorder acceptance of the data. The process continues until a nominal 100 nautical miles of that spectral band have been recorded; then the formatter-buffer repeats the operation for the next spectral channel, thus making four (or five) passes through the original MSS tape. The output format for MSS imagery is the same as for RBV pictures, including geographic tick marks, grey scales, and annotation. The identification number, however, will indicate that it is MSS imagery.

Bulk II processing is similarly like that used for RBV imagery except that the computer prepares an artificial reseau grid for geometrical correction derived from observatory attitude data (see Volume 2). Since the same model is used to correct all MSS images in a set, the inherent MSS registration is unaffected. Subsequent photo processing, preparation of color composites, and duplication for distribution is identical to RBV procedures.

3.1.4.2 Bulk Processing Hardware

The non-ADPE hardware used in bulk processing consists of:

- RBV tape reproducer provides for playback of RBV video bulk tape
- MSS tape reproducer provides for playback of MSS video bulk tape

- RBV bulk process control unit provides required interface between the RBV tape reproducer, computer, and high density tape recorder
- MSS bulk process control unit provides required interface between the MSS tape reproducer, computer, and high density tape recorder
- High density tape drive provides for recording and playback of digital data
- High density tape control unit provides required interface between the high density tape recorder and the computer
- Tape-to-film control unit provides required interface between the high density tape reproducer and the laser beam recorder
- Laser beam recorder provides for conversion of analog data to photographic images on film.

This equipment is described in Section 3.7.

In addition, the precision photo restitutor used in bulk II processing is described in the material on optical processing methods (Section 3.1.6) as well as in Section 3.7. Photographic printing and processing equipments are described in Section 3.2.

3.1.4.3 Image Processing Software-Bulk Modes

The NDPF software is organized into five functions, where a function is a group of computer programs working together to perform a major task. Each function is subdivided into modules in which a module consists of a single computer program. Each module is subdivided into routines. A routine is the smallest collection of serial codes which has recognizable input and output, and performs one or more tasks. Each software element operates under computer control by the operating system executive and under manual control by the operator. A complete GDHS software summary may be found in Section 6. The software specification (Milestone B) forms a part of the appendix to this volume.

The processing of an image begins with the reading of control cards. These identify the image of interest, provide the information necessary to permit the extraction of required data from other files, such as the

attitude/ephemeris time history tape, specify the operation to be applied to the image, and supply processing parameters desired.

The image to be processed is either read from high-density tape or loaded directly from the RBV bulk line control unit. If a geometric correction is required for MSS imagery, observatory attitude and altitude data is needed, and the appropriate tape is searched. Reseau detection is performed for all RBV imagery as described in Section 3.1.3.

Observatory attitude and attitude rates are estimated by using a weighted least-squares estimator to process ground truth, horizon scanner, reaction wheels and dual-gyro gyrocompass. The accuracy of the estimation is increased by using the dynamic equations of motion which contain all factors affecting the observatory attitude. In either bulk processing mode, sun angle, subsatellite point, frame center, frame corner coordinates, and locations of even degree and half-degrees (by interpolation) on imagery are computed.

The data base function is called to generate the annotation tape for each image. The annotation text consists of the following:

- Geographic tick marks
- Registration fiducials
- Sensitometric strips
- Identification number
- Picture time to the nearest 0.01 second
- Subsatellite point in geographic coordinates
- Spacecraft attitude
- Sun angle
- Receiving station
- Orbit number
- Picture center in geographic coordinates
- UTM designation of picture center
- Heading

- Deviation of UTM grid from meridians
- DCS data available for the image area
- Satellite designation
- Date of processing
- Cloud cover in tenths by quadrants
- A group reserved for coded remarks.

With the preprocessing portion of the data base generation function completed, the attitude determination function is called. The attitude determination function provides the initial attitude determination mode in preparation for bulk processing.

The external equipment control provides top-level control for RBV and MSS bulk processing. It interfaces the RBV and MSS bulk control units to provide control to the RBV and MSS reproducers and high density tapes.

The image generation control provides control for the precision photo restitutor when operating in the computer-controlled mode. The computer-controlled mode drives the precision photo restitutor to prepare a corrected RBV or MSS image based upon reseau computations. The film is then developed for archiving and to meet user requests. The computer-controlled mode provides corrections based upon the spacecraft attitude and position for MSS images, and derives corrections based upon reseau positions, to drive the four computed incremental values (x-position, y-position, zoom, and rotation) required by the precision photo restitutor. It should be noted that the imagery and related information are transferred to the archives. The software function to perform the data handling for generation and maintenance of archival files is the information management function. The information management function also processes user inputs into the archival files.

3.1.5 Precision Image Processing

Certain users of both RBV and MSS imagery will require geometric and other corrections to a degree of precision which exceeds that

achieved through the bulk process described above. The quantity of imagery to be precision processed will be a small fraction of the total received imagery, on the order of 5 percent. The very high accuracy required, and the complexity of the desired corrections, make all digital processing mandatory (see Volume 2, and Volume 17, Section 2 for accuracy and error analyses). The processing techniques to be applied are described in terms of the types of corrections available; the more complex corrective algorithms requiring considerably longer computer running times.

3.1.5.1 RBV Precision Processing

The precision processing of RBV imagery is defined in two parts: precision processing I and precision processing II (NASA option). A summary description of the features provided in each is followed by a more detailed explanation of the processing methods in Section 3.1.5.3.

The precision digital image processing system is implemented on a general-purpose computer with character manipulation instructions. This permits the processing algorithms to operate on data quantities commensurate with the precision of the input data and makes efficient use of the central processor and memory. The features of the processing are:

- Geometric correction performed by biquadratic interpolation. This is an accurate method of applying geometric corrections, leaving low residual errors
- The introduction of spacecraft attitude data, specific ground truth information, and verified ephemeris data. The effect of this information is to provide a fine adjustment to the reseau computation procedure and to increase the accuracy of the annotation, particularly geographic location.
- Provision for providing UTM or oblique Mercator projection mapping. The corrections for the UTM coordinates are used, via a look-up procedure, to adjust the calculated reseau corrections to provide a fine reference shift corresponding to the required projection correction.

In addition, a complete set of machine procedures can be provided to perform other manipulations which can be treated in a special request mode. These constitute precision processing II, and include:

- Structural noise removal, utilizing Fourier transform and convolution techniques
- Special image transformations, such as to other than UTM coordinates, applied as fine corrections to the reseau correction routine
- Photometric corrections for blemish removal by table look-up
- Reseau removal and cosmetic fill-in of removed points (available in reseau detection routines as an option)
- Radiometric correction for atmospheric effects
- Image enhancement, such as contrast stretch of selected intensity range or edge determination by low pass/high pass filtering.

The natural product of these two types of processing is a digital tape providing the image data in a coordinate system of equally spaced points and embodying all the corrections. This is duplicated for distribution to the users in response to requests for data in this form. When requested the corrected digital tape is used to produce corrected images from the laser beam recorder. The output format is the same as for bulk processed material, except that the identification number indicates the proper level of processing. Photo processing, duplication, and preparation of color composites follows the same procedures as for the bulk products.

3.1.5.2 MSS Precision Processing

The precision processing of MSS image data parallels that of RBV image data very closely. All the standard and special request processing done on RBV imagery can also be done on MSS imagery, except for blemish and reseau removal, since these are not present in MSS imagery. The precision processing of MSS image data is all digital and leads to the production of computer-readable tapes and laser beam recorder film output in the same manner as that described for the RBV image data.

One significant additional operation is included in the precision processing of MSS data, in order to improve the attitude data inputs to the computation of distortion corrections. In this operation one RBV

precision image corresponding to the same MSS spectral channel and ground coverage is used as a control image in the precision photo restitutor. The MSS image, which may be obtained from either bulk I or II processing, is optically correlated against it. The values of the optical adjustments necessary to achieve correlation are sent to the computer, but no output print is made. A very accurate estimate of yaw angle can be made by taking the properly weighted average of all the y-displacements, each divided by its corresponding x-distance from the center of the picture. This technique does not involve correlation between different spectral channels, nor does it depend on achieving correlation over the entire image. A relatively small number of values provides a good estimate of the yaw angle; as the number of available values increases, the accuracy of the estimate is improved. Moreover, the precision photo restitutor provides an indication of the degree of correlation achieved at any time, so that doubtful data can be eliminated from the inputs to the computations. By this procedure, the advantages of correlation methods are exploited without incurring any hazards associated with areas of failure or degraded confidence in the correlation output. The improved yaw values derived from this method are merged with other attitude data, and the overall best set, including inputs from telemetry, ground truth measurements, and correlation, is used to develop one distortion model for use in subsequent digital processing of all the MSS spectral channels covering the same area. One distortion model is used to correct all the MSS images so as to preserve the inherent registration of the MSS images.

3.1.5.3 Precision Processing Operational Description

Two operational modes of precision image processing have been defined and include, respectively, the following procedures:

1) Precision Mode I

- Geometric correction of RBV using reseau, attitude, and ground truth data
- Correction of MSS using attitude, ephemeris, ground truth, and correlation data

- Image transformation into UTM or oblique Mercator coordinates

- Shading and gain correction.

2) Precision Mode II (NASA Option)

- All of precision mode I corrections

- One or more of the following:

  RBV blemish removal
  Image motion compensation
  Image transformation into specified grids
  Image enhancement
  MTF correction
  Structured noise removal
  Reseau removal with cosmetic fill-in
  Radiometric adjustment for atmospheric effects
  Nonstandard composite color balance.

Processing for any image begins with the reading of computer control cards. These identify the image of interest, provide the information necessary to permit the extraction of required data from other files (such as the attitude/ephemeris), specify the operations to be applied to the image, and supply any processing parameters which are under the control of the user.

The image to be processed is either read from high-density tape or loaded directly from the RBV bulk line control unit and may be stored in direct access storage. For performing geometric correction, spacecraft attitude and altitude data is needed, and the appropriate tape is searched.

Precision I processing normally includes the measurement of ground truth points. These provide inputs for the improvement of spacecraft attitude data, and are logically introduced into the procedures at this point. Since ground truth measurements are time-consuming (about 1 hour for data applicable to each set of RBV and MSS images) they will have been initiated as soon as the request for precision processing has

been identified, and completed before the computer processing is started.

Image data which has been stored in direct access storage is read into memory for processing. The geometric correction routines used in digital processing are essentially the same for both RBV and MSS image data. The differences occur in the sources of data from which the coordinate transformations to obtain corrected output geometry are derived. For RBV imagery, these are reseau measurements principally, with attitude data as inputs to projective corrections. For MSS imagery, they are attitude and attitude rate data, modified by spacecraft dynamic modeling, Kalman filtering, ground truth measurements, and correlation results.

If the image being processed contains calibration data, the appropriate photometric calibration tables are computed. Structured noise is characterized and/or removed upon request. Since several images may be required for noise characterization, it is possible that characterization but not removal will be requested. Single-point photometric and radiometric corrections are applied to RBV or MSS images as requested. These corrections may adjust for shading and gain errors as well as perform precision mode II options such as atmospheric scattering compensation, gamma correction, and application of simple image enhancement procedures such as thresholding and video "stretching". If RBV multi-point photometric corrections are to be applied, the single-point correction is deferred and applied later as a combined operation.

Reseau and blemish removal are performed on RBV images if desired. If a geometric correction is required, the appropriate mapping function is computed, and the correction is applied through interpolation techniques. The correction may include transformation into any one of a list of preprogrammed coordinate projections.

Multi-point photometric and radiometric corrections are applied as requested. These may include IMC and MTF corrections as well as selections from a list of image enhancement techniques which can be

implemented through use of a multi-point space domain operator of moderate size.

The imagery is recorded on film by the laser beam recorder as in bulk I, except using the corrected tape and thus incorporating the results of the digital processing. Options available to users include gamma increases or decreases for individual spectral channels in accordance with user specifications, and nonstandard false-color composites in which the relative gains or allocation of printing colors to spectral bands are specified by the user.

Provisions exist for outputting image data, annotation, and shading correction data on high-density and 1600 bpi tapes as required. Since precision processing, as discussed above, is digital for both RBV and MSS imagery, the digital tape outputs automatically contain all corrections which have been made.

3.1.5.4 Precision Processing Hardware

The non-ADPE hardware used for precision image processing is the same as that used for bulk processing, with the addition of a ground truth (geodetic) measurement station. The use of the ground truth station is discussed in Section 3.1.5.6, and the equipment characteristics are given in Section 3.7.11.

The precision photo restitutor is used in a different mode in precision processing. The correlation capability of the device is used to obtain error signals derived from correlation of an RBV precision image as control with an uncorrected MSS image lying in the same spectral regions. These signals are used by the computer to improve spacecraft attitude determination.

3.1.5.5 Image Processing Software Precision Processing

Requests for precision image processing are required before a precision process is applied to a selected RBV or MSS image.

Upon receiving a request for precision processing, a file search is made to determine if the desired imagery is available. If such imagery is available, it is reproduced and disseminated. If the requested imagery is available but not in the desired quality, precision processing is

initiated in the NDPF. Should imagery covering the requested temporal or spatial conditions not be available, the OCC and the originator are notified.

The additional software routines above those used in bulk modes and which are necessary to support the procedures listed in Section 3.1.5.3 are described in Section 6 of this volume as well as in the Software Milestone B appendix.

3.1.5.6 Ground Truth (Geodetic) Measurements

For precision processing, the data available for estimating both internal geometric errors of the imagery and the absolute image location information given in the annotation data are augmented by measurements made on image points identifiable on both the ERTS imagery and existing maps. The maps are obtained primarily from the U.S.G.S. and U.S.C.G.S. Total U.S. map coverage is available at 1:250,000 (about 500 maps), 40 percent coverage is available at 1:25,000 (about 24,000 maps), and 60 percent coverage is available at 1:62,500 (about 8,000 maps).

Map geodetic control accuracy is a function of map scale, since maps are constructed to national map accuracy standards, in terms of allowable error for map production. The national map accuracy standards require that the points mapped shall lie within 0.02-inch of their correct position 90 percent of the time; this equates to 420 feet, 42 feet, and ~100 feet for the scales mentioned. Thus, the map scale of 1:25,000 will be used whenever possible.

The map and photographic geodetic control mensuration station consists of a unit which allows simultaneous viewing of a frame of RBV or MSS image with two different scale maps on 70 millimeter film. The accuracy needed in ground truth measurements is approximately 6 micrometers over the 9-1/2 inch-square format. This accuracy requirement with the full format viewing plus the requirement for measuring two 70-millimeter film strips with the map information either at the same machine or a separate machine is satisfied by a modified OptoMechanism Model 527-A comparator.

This machine is a dual light strip comparator with motorized film drives capable of handling both the 9-1/2 inch and two 70 millimeter films simultaneously. The comparator is modified with direct coupled encoders and an automatic data logger tied to an IBM 526 summary punch station. The accuracy required is maintained with a calibration program in the computer.

The degree of correction required establishes the number of control points necessary for the accuracy desired. A matrix of nine control points used in conjunction with pitch and roll data assures that the geodetic error is ±980 feet or less (see Volume 17). One of the nine points should be near the picture center; the remaining eight points should be near the corners and midpoints of the sides of the photograph. With the measurement of nine such points to an accuracy of ±5 micrometers, the resulting geodetic control errors are illustrated in functions of map scale in Figures 3-4 through 3-7.

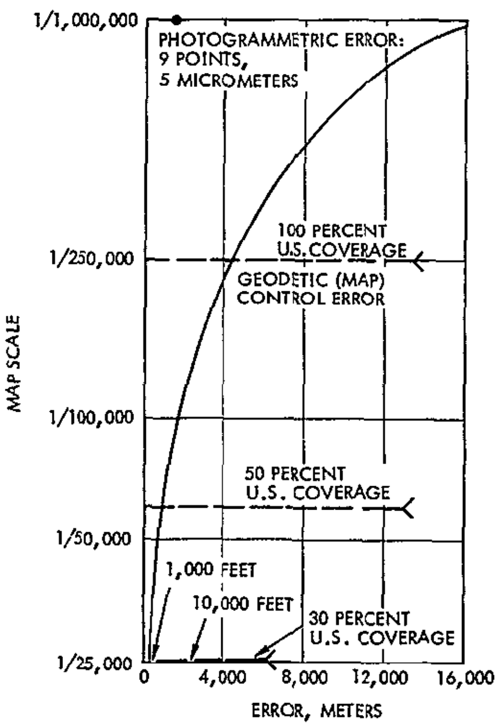


Figure 3-4

ONE-SIGMA PLANIMETRIC ERROR
using nine control points

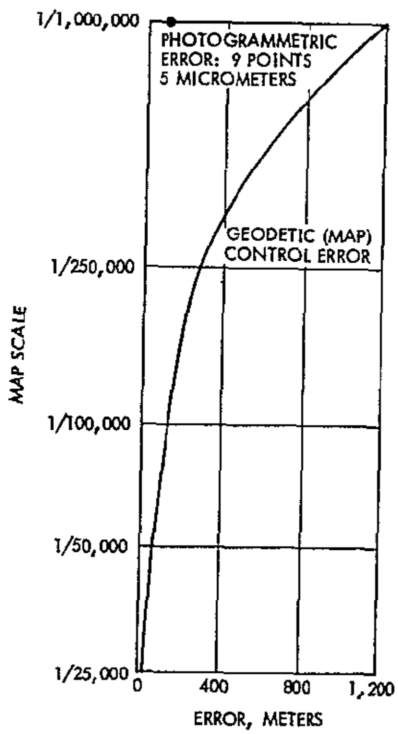


Figure 3-5

ONE-SIGMA VERTICAL ERROR
using nine control points

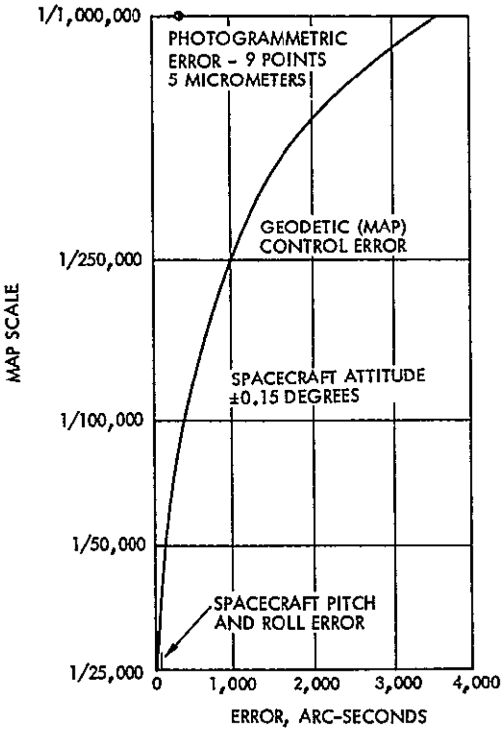


Figure 3-6

ONE-SIGMA PITCH AND ROLL ERROR from nine control points

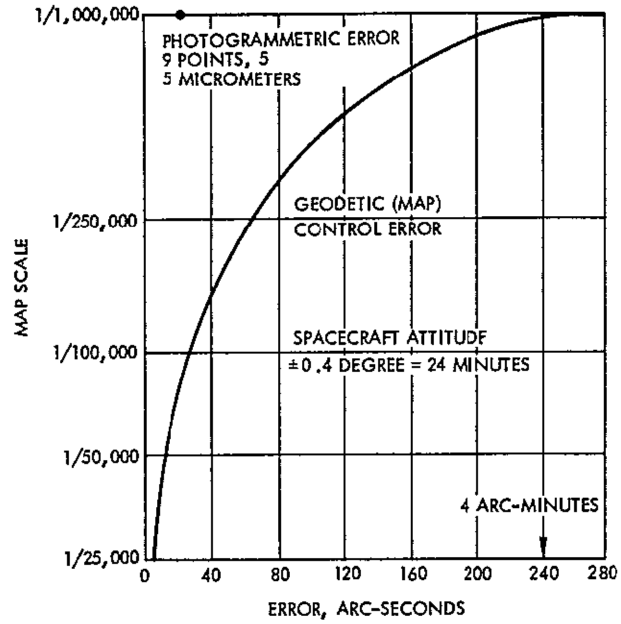


Figure 3-7

ONE-SIGMA AZIMUTH ERROR from nine control points

In the ground truth measurement procedure the first step is placing the RBV imagery on the viewing stage. The geographic location of the imagery is determined from the RBV image frame (lower left corver in direction of flight), and the roll(s) of map film containing the proper map coverage are selected from the map file and placed on the viewer. The RBV image to be measured is clamped to the viewing stage by the glass pressure plate provided on each stage of the viewer. Three of the four registration marks (upper-left, upper-right, and lower-left are pointed and x and y coordinates for each are recorded. Map coverage coinciding with RBV coverage is located and clamped in place. By comparing the RBV and map images, control points visible on both the map(s) and the RBV imagery are selected. Their precise x and y coordinates, elevation, and scale are recorded from both the RBV imagery and the map (preferably the 1:25,000). These data are placed in the proper format on the punched tape to be used in the precision photo restitutoe in conjunction with the ephemeris data, resear measurements,

and other data supplied with the RBV imagery. The data to be extracted at the map and photographic station consist of:

- X, y coordinates of three of the four registration fiducials (upper-left, upper-right, and lower-left in the direction of flight)
- X, y coordinates of the center reseau point on the photograph
- X, y coordinates, elevation, and scale of the picture center from the map(s) (to be used with appropriate scale programs)
- X, y coordinates of each geodetic control point from the RBV imagery
- X, y coordinates, elevation, and scale of the identical geodetic control points from the map(s).

3.1.6 Precision Photo Restitutor

The device which is used for optical correction of internal geometric errors in the bulk models and detection of yaw attitude errors in the precision modes is the precision photo restitutor. The precision photo restitutor employs an optical system to give zero- and first-order transformation to the images in a linear piecewise approximation to the correction function, developed from reseau measurements, spacecraft data, and ground truth, if necessary.

A simplified block diagram of the precision photo restitutor is shown in Figure 3-8. A scanning table driven in x and y carries the input, control, and output film rolls. The output film is exposed by an image that is transformed from the input image by optical elements capable of introducing magnification, rotation, Δx and Δy corrections.

These corrections are normally programmed for computer generated data, or they may be developed by the corrrelation system that detects relative distortion between the control image and the input image. A printing slit of 0.811 by 0.05 inch has been selected for bulk processing. Thus, nine printing segments are exposed over the image format.

Figure 3-9 indicates the scan process for film exposure in the precision photo restitutor. In the computer controlled mode, the scanning

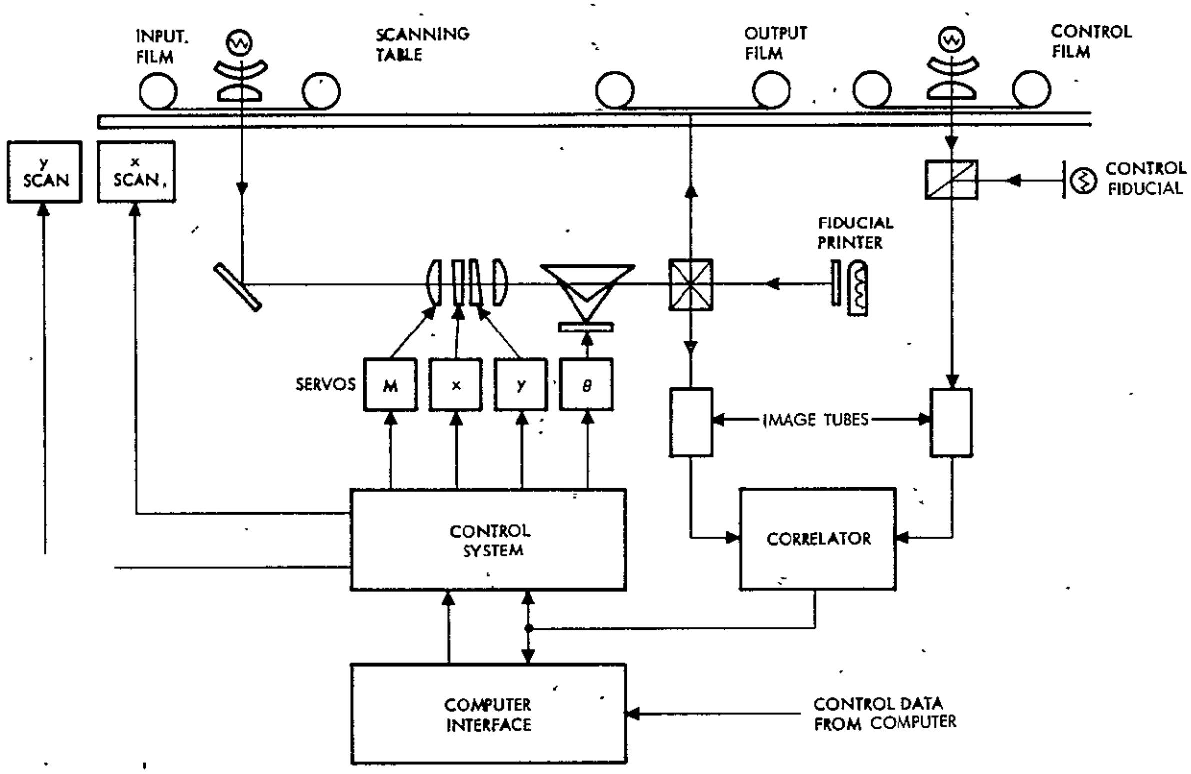


Figure 3-8
PRECISION PHOTO RESTITUTOR simplified block diagram

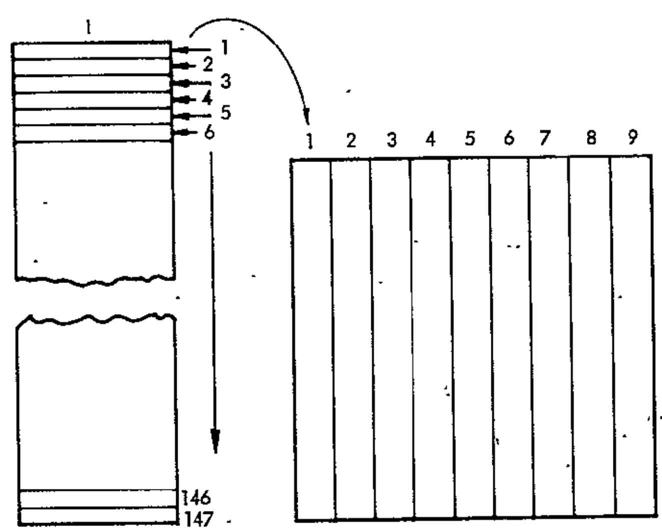


Figure 3-9
PRECISION PHOTO RESTITUTOR
SCAN PROCESS for film exposure

table is positioned to enable strip number 1 to be printed. The exposure slit allows the film to be exposed, in a continuous fashion, as the table moves at a constant rate. During printing, the optical system is continuously controlled by computer generated data in order to shift the elements of the image within the slit in such a fashion to correct distortion. After each strip is printed, the scanning table is stepped to the next strip and the process is repeated.

3.1.6.1 Optical System

The precision photo restitutor printing and correction systems have been made as simple as possible, consistent with the requirements in order to maintain highest positional accuracy. Since film positioning tolerances are especially critical differential displacements of input are accomplished in the optical system to avoid complicated film drive mechanisms.

The method used to obtain the required ±5 percent change in magnification from unity image reproduction is to make the printing relay a symmetric pair of lenses and move the lenses separately so as to accomplish the required change in magnification and still maintain focus in the image.

The device which provides the required image rotation of ±2 degrees is a K-mirror assembly adapted directly from a previous design. A beamsplitter is included in the K-assembly to fold the printing relay optical axis 90 degrees to the output film plane and to provide simultaneously an image for the input correlator. Space limitations dictate the placing of the fold inside the K-housing. The beamsplitting optical device has neutral spectral transmission and reflection. A solid glass cube beamsplitter has been indicated in the optical system schematic, Figure 3-10. Suitable compensation for the aberrations introduced by the glass cube in the relay optical path may be applied in the form of corrective optical elements. In the event that the relay lenses are special designs, compensation for the beamsplitter can be designed into the lenses. An alternative solution is to replace the cube with a thin membrane beamsplitter (pellicle).

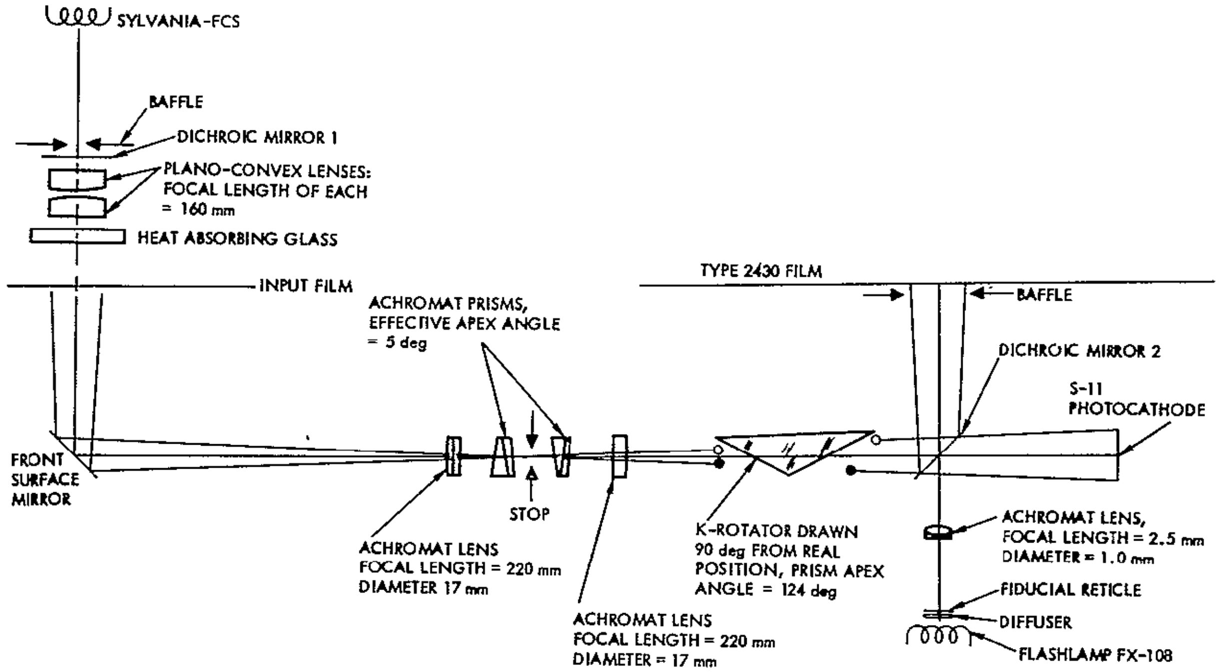


Figure 3-10
FIRST-ORDER OPTICAL DESIGN for precision photo restitutor distortion correction

Differential displacement corrections between input and control photographs are introduced by means of deflection of the printing relay optical axis rather than by direct differential translation of the input photograph with respect to the control photograph. The optical deflection is accomplished with rotating prisms located between the relay lenses in the optical printing path. The prisms consist of right circular cylindrical wedges each of which introduces a small fixed angular deflection into the optical path. When used in pairs, the wedge deflections can compensate each other so that, by rotating wedges with respect to one another, their net angular deflection can be varied from zero to twice that of a single wedge.

Four separate achromatic wedge prisms are used to provide deflection along Cartesian x-y axes. Each pair of wedges provides deflection only along one axis. The wedge angle of each prism for deflection of ±11 millimeters in the input film plane is approximately 1.5 degrees depending on the refractive indices of the glasses used to make up the prisms. Deflection produced by each prism pair in the precision photo restitutor is a

function of both the mutual rotation angle, β, and the distances from the input film plane of the relay lens which is between the input film and the prisms. The servo-system driving the prisms must thus receive inputs of both the amount of deflection required (Δx), and the position of the relay lens (Δs).

A photometric analysis of the precision photo restitutor printing (input/output) loop indicates that a 500-watt tungsten iodine projection lamp similar to the Sylvania FCS lamp will have appropriate power output and spectral radiance to adequately accommodate all expected modes of operation. The radiance of the lamp in the spectral regions of interest is sufficient to permit:

- Black and white printing on EK film type 2430 (with the appropriate filters)
- Printing of false two- and three-color prints on color reversal film type 2448 (SO-151)
- Visual alignment and testing
- Light for proper operation of both the control and input/output vidissectors.

The condenser system used to project the source (filament) is of conventional design. The condenser optics also provide for the elimination of unwanted radiation at long wavelengths (greater than 0.7μ). This is accomplished by a dichroic mirror positioned in the system so that the unwanted spectrum is directed at an angle of 90 degrees away from the light path. This radiation (~0.7 - 0.9μ) is sensed by a silicone photodiode to monitor the output of the lamp.

Color separation for production of false-color prints is accomplished by selective filtering at the output. Spectral bandpass filters are used to isolate the color bands. These filters are of appropriate spectral characteristics or neutral density. They are located as near to the output film plane as possible on a rotating disk so that the different filters can be quickly and easily interchanged.

The optical performance of the system in terms of modulation transfer functions has been calculated. Diffraction at the aperture stop

of the relay is the first degrading factor. The MTF of a diffraction limited f/20 imaging cone is represented by curve A in Figure 3-11. The surface irregularies of the five mirrors also reduce the image quality. If the mirror surfaces are 1/10 wavelength peak-to-peak, then the modulation loss due to the five mirrors is illustrated by curve B. Defocusing also results in modulation loss. The effect of maximum defocusing is illustrated by curve C. Another source of modulation loss is the duplicating film. The MTF of type 2430 film is represented by curve D. The effect of mirror vibration and other minor sources of aberrations are budgeted into curve E. Curve F represents the product of curves A through E; it therefore is the system MTF for fixed values of magnification, rotation, and translation, under static conditions. Image smear produced by magnification changes, rotation changes, and translation changes that occur as the scanning slit moves one slit width have been estimated for worst case geometry corrections. The expected system MTF's during dynamic correction are:

0.05 x 0.8 inch slit: 50 percent system response at 10 lp/mm

0.05 x 0.4 inch slit: 70 percent system response at 10 lp/mm

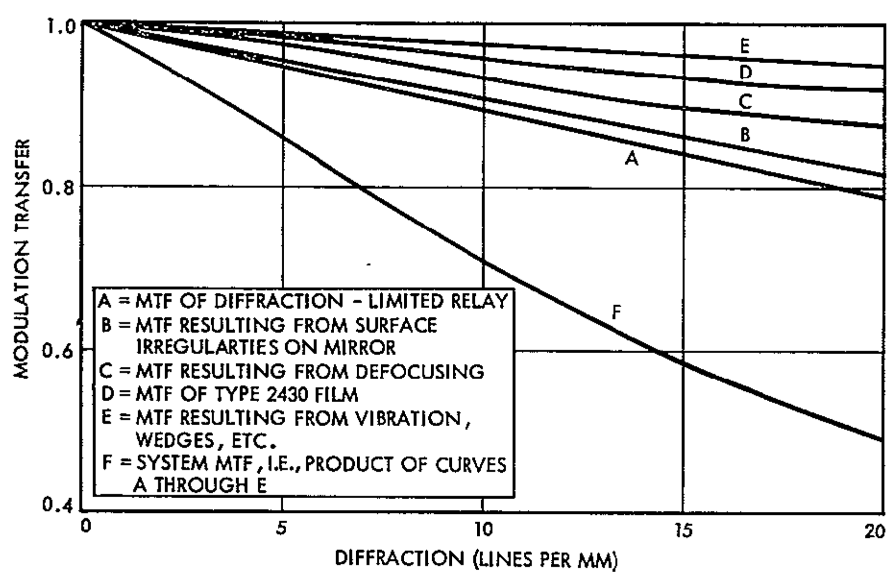


Figure 3-11

TRANSFER FUNCTIONS FOR precision photo restitutor optical system

3.1.6.2 Correlation System

The correlation system incorporated in the precision photo restitutor is similar to the system employed in the Itek EC-5 Planimat. The major difference is the use of image dissector tubes in place of cathode-ray tube scanners and photomultiplier detectors.

The scanning system consists of two image dissector tubes (vidissectors) that are integrated within the input film path and the control film path. One of the vidissectors scans the input film image through the same optical train used to generate the corrected output image. The other vidissector scans the control image. The film images are illuminated by backlighting condensors and tungsten lamps so that the vidissectors receive light that is transmitted through the film image. By scanning the images with a special raster pattern, the vidissectors convert the density variations on the film (and hence transmission variations) to one dimensional analog electrical signals. The two video signals from the vidissectors are fed into the electronics rack. Here the signals are correlated and analyzed into zero- and first-order error coefficients: x-y parallax, x-y scale, x-y skew. Error signals are generated proportional to these correlation errors between the input image and the control image, and are used to drive servomotors attached to the optical correcting chain. Compensating amounts of parallax, skew, and scale are introduced by the optics until the input image (as viewed through these optics) achieves maximum correlation with the control image.

The electrical outputs of the correlation system are signals indicating acceptable correlation quality and the error signals for x-position, y-position, rotation, and magnification. To provide error signals that are essentially independent of image quality and detail, high-speed adaptive correction loops are used to apply scanning raster corrections such that the images appear to be registered to the electronic system. Thus, the error signals are derived from the amount of correction applied to the rasters.

Each image is scanned in a continuous fashion by means of triangular waveforms imposed on the image dissector deflection circuitry. To

provide a relatively constant video signal output from the wide variations in image density and contrast, dynode regulation is used on the photomultiplier section of the image dissector to normalize the dc component of the video output, and fast automatic gain control is applied to video amplifiers to normalize the high frequency signal obtained by scanning the image detail.

The two normalized video signals from the left and right images are multiplied in the video correlator circuitry contained in the electronics chassis. To give both wide pull-in range for the system and high accuracy of registration, three parallel correlator bands are provided. The correlator provides two outputs for further analysis. One output, called the orthogonal correlation signal, is proportional to the instantaneous time displacement of the two video signals. Thus, this output is zero under conditions of perfect image registration. The other output signal, called the normal correlation or cross-correlation function, is proportional to the degree of total image registration, and thus is maximum when the two images are in registration.

A summary of the correlation system performance follows:

- Scanning System

  F4011 image disector (ITT) with S11 photocathode

Aperture:	0.005 inch
Scanning raster:	Dual-diagonal diamond with 31 line resolution
Electronic zoom:	4:1
Frame rate:	560 Hz.

- Correlation Outputs

Translation error:	Nominal pull-in range, ±4 mm Accuracy, ±30 micrometers
Magnification error:	Pull-in range, ±5 percent Accuracy, ±0.3 percent
Rotation error:	Pull-in range, ±2 deg Accuracy, ±0.1 deg

Correlation quality signal: Signal shall be high when the correlator can pull in and obtain useful error signals. A low level indicates correlation failure.

3.1.6.3 Computation and Control Requirements

In the computer-controlled mode, the precision photo restitutor first reads the position of three (or four) frame fiducial marks, enters the data into the central computer, and then prints out the image under computer control.

The programs required for precision photo resitutor operation are summarized below:

- Correlation Array Calculation. Data from reseau measurement, spacecraft attitude, sensor calibration, ground truth, and other sources are used to calculate a set of nine 4 x 147 matrices which provide the precision photo restitutor with optical element settings for correction of an entire image. In addition, instructions for control of scanning table position are provided at the beginning of each printing strip. The data rate for optical element settings of x, y, m, θ is 100 bytes (8 bits per byte) per second.
- Initialization. The computer reads the precision photo restitutor frame fiducial positions, and transforms the nine 4 x 147 correction array to precision photo resitutor coordinates by adjusting all x, y, and θ values.
- Annotation Control. After an image has been printed, instructions are provided to the precision photo restitutor which initiate tick mark and tick mark label printing; and data block printing. Instructions include:

  Y table position for tick mark exposure

  X table position for tick mark exposure

  Tick mark label data

  Annotation table position

  Alphanumeric annotation data.

3.1.6.4 Precision Photo Restitutor System Performance Summary

The range of image geometry correction by the precision photo restitutor is more than sufficient to match the distortion in the imagery of the various ERTS sensors caused by spacecraft attitude errors and

sensor distortions. In addition, the precision photo restitutor is designed as a high-production rate processor for operation in a photographic laboratory environment with minimum personnel attendance and maintenance requirements.

The ability of the precision photo restitutor to provide differential correction of input image geometry meets or exceeds specified requirements. The precision with which corrections are made has been determined by an error analysis of the proposed precision photo restitutor design (see Volume 17). The individual contributions to the total error include:

- Setting accuracy in x-y position of both input and output relative to printing slit of 20μ rms over 8 x 8-inch format.
- Differential image displacement in both x and y of up to ±11 mm with setting precision of 10μ rms.
- Differential magnification range of 0.95 to 1.05 ±0.2 percent about nominal magnification of 1.0.
- Differential image rotation of ±2 degrees with setting precision of ±0.1 degree rms.
- RMS correlation accuracy at center of printing slit-bulk process mode = ±60μ, precision process mode = ±30μ.

This error analysis leads to the following performance when used in a computer controlled mode, assuming no external errors.

Residual error,	with 0.05 x 0.8 inch slit:	±182 ft
	with 0.05 x 0.4 inch slit:	±130 ft

In a correlation mode, assuming no residual errors in the control image, the following performance is indicated:

Residual error:	with 0.05 x 0.8 inch slit:	±260 ft
	with 0.05 x 0.4 inch slit:	±145 ft

Overall Image Quality

There is no variation in specified image quality over the entire image format. The precision photo institutor adds no cumulative distortions or aberrations to the output image of magnitude greater than the precision limits of corrective elements and correlator as specified above.

Static Performance

Since the sensor input imagery is not likely to have modulation beyond 10 lp/mm the precision photo resitutor system MTF is measured and specified at 10 lp/mm. The precision photo restitutor system MTF is expected to equal or exceed 75 percent relative response at 10 lp/mm.

Dynamic Performance

The precision photo restitutor system MTF will be degraded from the specified static performance value during dynamic correction of input photo-geometric errors. The degree of degradation is approximately proportional to the degree of image correction required. Estimates have been made for system MTF during dynamic correction of worst case spacecraft attitude and sensor distortion mismatch as indicated in Volume 17. Expected system MTF's during worst case geometry corrections are:

Bulk process mode (0.05 x 0.8 inch slit)	50 percent system relative response at 10 lp/mm
Precision process mode (0.05 x 0.4 inch slit):	70 percent system relative response at 10 lp/mm

Photographic Uniformity

In addition to faithfully reproducing the input imagery the precision photo restitutor does not add detectable cosmetic defects to the output film image due to variations in exposure (banding), multiple exposure (stripping), and distortion.

- Banding. Periodic variations in image density along the direction of slit scan will have peak-to-peak amplitude of less than 0.02 in density.
- Stripping. There will be no detectable stripping due to overlap or underlap of adjacent scan strips.
- Processing Efficiency. The precision photo restitutor will process input photography on continuous film rolls at the following rates depending on the process mode.
- Bulk Process Mode. 2.5 minutes or less per output frame.

- Precision Process Mode. Four minutes or less per output frame.

- Additive Color. Three minutes or less per output frame per input color overlay.

The rates indicated above include time allowances for printing of all geographic tick marks, registration fiducials and data block with 5-second allowance for film frame advance.

Additive Color Printing

Provision is made in the precision photo restitutor for additive color printing of multispectral inputs using EK color reversal film. Overlay registration accuracy of ±30 micrometers rms is maintained. Up to five false-color bands may be printed on a single-color output frame.

3.1.7 Digital Image Processing

The studies reported in Volumes 2, 15, and 17 indicate the need to handle nonlinear distortions in sensor image geometry and photometry. In addition, the ability to control a sequence of such operations automatically leads to a choice of the digital approach for precision image processing. Certain image processing corrections have become standardized to the extent that such may be used for any particular application. These routines include noise removal, geometric distortion correction, photometric distortion correction, cross-correlation of two picture overlap regions for superposition, reseau detection and removal, spatial frequency recovery (enhancement), and others which are more camera specific. All these operations can be used for ERTS, with major emphasis on geometric distortion correction and reseau detection.

The input parameters for geometric distortion correction are derived from the reseau positions as seen by the RBV cameras and from the observatory coordinates as available in attitude telemetry and ephemeris data. To create a corrected image, it is preferable to establish a coordinate system in which the corrected picture contains equally-spaced points. This equal spacing avoids the serious problem of moire patterns created by uneven line spaces and the possible spurious intensity variations even though the image is prepared with equal intensities input per point. This

uniform output grid then is transformed to a nonuniform original mesh as laid out on the input data, which artificially are presented as uniform with time.

As the final coordinate mesh is transformed to input space coordinates, points are chosen as reference positions at distances close enough to allow interpolation to well within a picture element yet far enough apart so that calculations concerning positions are reduced with respect to this operation for every point. These points can be related by nonlinear analytical means to the errors of translation determined for the more coarsely located reseau positions. An efficient routine has been written to interpolate within this linear region and detailed computations have been performed to apply this algorithm to a variety of processors.

3.1.7.1 Reseau Measurement

Reseau networks provide a means for obtaining a measure of geometric distortion in each RBV image. Current design provides a mesh of 9 x 9 reseau marks for each RBV camera. These reseau marks are crosses, which are particularly useful for human reading, although dots have proven satisfactory, occupy less area, and are more amenable to computer processing. As the camera surface is scanned, any irregularity in beam positioning is reflected in an apparent translational displacement of the reseau network. As each reseau mark is located, a vector of displacement is calculated between actual and desired position. This vector is used as input to the geometric distortion correction.

The reseau measurement procedure is basically a digital correlation routine performed in the computer with a pre-established model to correlate the image data against, and performed over a restricted area in which the reseau mark is known to be located.

The following sequence of operations is performed to locate the reseau net:

- Correlate the model of the reticle in the vicinity of previous locations
- Follow correlogram "object" edges and discard those not circumscribable by the expected size

- Cluster candidate reticles to define consistent array of reticles, i.e., one per logical position

- Interpolate or extrapolate missing reticles in the array

- Remove and log locations of established reticles (optional)

Computer input/output time is saved by assuming the reseau marks lie close to selected bands of sequential scan lines. These lines are read from intermediate storage as needed. The total set of probable reseau marks is transformed into a list of (x, y) coordinate pairs representing the centers of each, and the analysis for the best set is derived from that list. Analysis indicates that individual reseau points can be located to better than 0.1 pixel. Missing reseau marks are supplied from the accumulated and constantly updated history.

For MSS imagery direct computation of the corrected location of each ground point from spacecraft attitude and ephemeris data would require an unacceptably long time; it is more efficient to compute ground points (latitude and longitude) for a small number of reference points and generate an artificial reseau to correct intermediate points. Thus the processing of MSS imagery can be effected identically to the processing used for RBV imagery. The computation of the artificial reseau points requires a very short time, and the reseau correction time is comparable, but less than that for processing the RBV pictures because of the reduced number of image points. The number of reseau points obtained for the MSS is large enough so that modeling plus estimation errors are less than the internal consistency errors of the reference points (500 to 900 feet one-sigma).

3.1.7.2 <u>Distortion Correction/Coordinate Transformation</u>

With the data derived from reseau measurements (RBV) or the equivalent derived or artificial reseau (MSS), the process of performing geometric corrections of both RBV and MSS images is equivalent to coordinate transformation. The procedures selected fall into two classes: interpolative and total image function operators.

The image data may be regarded as a function of two dimensions which gives the photometric intensity as a function of distorted position

(x', y'). More explicitly, consider an input array of intensity values $[R_1(I', J')]$, each of which represents an intensity measurement at that particular distorted location. Each distorted location corresponds to an undistorted location (x, y). If a square output array, $R_2(I, J)$ is desired, consisting of a rectilinear array which gives the intensity as a function of undistorted position, the following procedure is used. First, fit the measured positional displacements of the reseau points to obtain estimated distortion functions of the form

$$x' = f_E(x, y) \qquad\qquad y' = g_E(x, y)$$

These equations then are used to calculate the distortion of any desired undistorted point (x, y). That is, a value of x, y is chosen, and the corresponding distorted position x', y' is obtained. The input intensity array is used to calculate the intensity at that distorted position. The resulting intensity value is the intensity of the point x, y. This procedure is summarized schematically in Figure 3-12. The accuracy of the procedures is governed by Stages I and III and computation time is determined by Stages II and III. Stage II is the geometric correction, while Stage III is the intensity calculation.

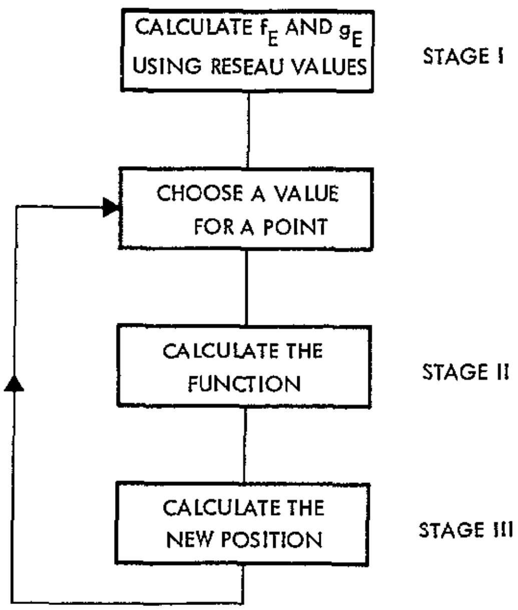


Figure 3-12
COMPUTATIONAL PROCEDURE

3.1.7.3 Image Internal Geometric Corrections

The transformation operation discussed above serves as the basis for establishing the detailed analytical operations for performing image geometric corrections. These operations are based upon models of the RBV and MSS distortions.

General expressions for the geometric correction error resulting from least-squares and interpolation fits to the reseau point displacements

are derived. These general expressions are then applied to specific fitting procedures. The detailed description of this analysis is contained in Volume 17 of the Phase B/C Study Final Report. The material below summarizes the conclusions as applied to the image processing design.

The distortions present in the image are of the form

$$x' = f(x, y) + \alpha \qquad\qquad y' = g(x, y) + \beta$$

where f and g are smoothly varying functions and α and β are random spatial noise. The functions f and g, called the functional distortion, contain terms arising from all smooth-distortion sources. The spatial noise terms arise from sources such as sync-jitter, beam pulling, and high-frequency distortions.

If the noise is spatially uncorrelated, that is

$$E(\eta_i \eta_i) = \delta_{ij} \sigma_N^2$$

at points i and j, then given the values of z_i for the reseau points, where

$$z_i = F(x_k, y_i) + \eta_i + m_i, \; i = 1, 2, \cdots, N_R$$

m_i represents the measurement error for the i^{th} reseau point. These reseau displacements may be fit by least-squares or interpolation to determine the estimated distortion function

$$z_E = F_E(x, y)$$

A summary of the results applied to the RBV using this model is presented below. Certain additions are made to accommodate the particular error sources associated with the MSS. Internal consistency in the MSS image is defined as the accuracy with which one ground point can be located relative to another. Thus, the internal consistency can be

found by differencing the absolute errors at two different points t_i and t_j in the MSS picture (taking into account the error-correlation between the two points). One of the two points, the reference point, is normally taken to be at the center of the picture. With the exception of uncorrelated noise, the internal consistency errors go to zero as $t_i \rightarrow t_j$, and the buildup of internal consistency errors with time separation, $t_j - t_i$, depends critically on the time as well as the spatial correlation of the error sources. The attitude determination errors are exponentially correlated in time as well as cross-correlated in roll and yaw. Terrain variations are exponentially correlated in terms of spatial separation in the picture. MSS alignment errors are constant in time with zero ensemble average. It is evident that the internal consistency is dependent strongly upon the assumed error-correlation model; this analysis is presented in expanded form in Volume 17.

3.1.7.4 Geometric Correction Accuracy

In the RBV images, fitting procedures to the 81 reseau locations are performed using a piecewise biquadratic technique. In this procedure, the measured positional displacements of the reseau points, derived from the digital reseau extraction process, are used to obtain distortion functions. The resultant equations, for the x and y directions, are then used to calculate the distortion of any desired undistorted point, i.e., the corresponding point in the corrected image. The accuracy of this approach is dependent upon the form of the distortion in the original image. The number and distribution of the reseau, and the function utilized. The approach used is an interpolative one, in which a regional subset of reseau points is selected and the positional displacements are fitted by choosing the parameters of a selected functional form. This fitted function then serves as a distortion function for that region. Of the candidate functions analyzed (see Volume 17), the biquadratic has been selected as providing the best fit. For this fitting function, nine adjacent reseau points are chosen and the nine reseau displacements at these points are used to determine the nine parameter biquadratic function. For the assumed image distortion, the biquadratic fitting function is characterized by a residual error of

0.1 pixel at the image center and 0.4 pixel at the image edge, when fitting the one percent cubic distortion term which characterizes the RBV image.

When the distorted position has been calculated for a given undistorted point, the value of the intensity at that distorted point must be obtained from the original image intensity array. The procedure selected, which is most accurate, is to utilize four-point interpolation. In this procedure, fundamentally bilinear in nature, all four adjacent points are used to interpolate the value of the intensity at the point. For the IBM 360/85 computer the time required, per RBV image, for the geometric and intensity calculation requires just under 3 minutes of central processing unit time.

It is to be noted that increased residual distortion at the image edge occurs since the reseau points terminate well before the actual image edge. The distortion function has been extrapolated smoothly beyond the last reseau point to the edge of the image. If the reseau points were to be distributed such that they occurred at the edge, the residual error would be decreased substantially, i.e., the residual error at the edge would be about 0.1 pixel, the same as in the image center.

3.2 PHOTOGRAPHIC PROCESSING

The principal functions of photographic processing in the data services laboratory are to reproduce, in accordance with standardized procedures, the imagery exposed in telemetry and image data processing and to respond to users' requests for nonstandard photographic reproduction. The standard and nonstandard products include black and white positive and negative film reproductions and positive paper prints, and color transparencies and prints. The photographic processing function is also responsible for preparing photo montages depicting the coverage obtained by the RBV's and the MSS in each 18-day cycle.

The following activities are involved:

- Develop the film exposed in the laser beam recorder and the precision photo resitutor
- Expose and develop intermediate film negatives and positives

- Expose and develop black and white and color film and paper reproduction for dissemination to the users
- Respond to user requests for special photographic products (e.g., nonstandard color reproduction, enlargements, additional copies, etc.)
- Perform quality assurance tests on all materials produced
- Produce photographic montages depicting the coverage obtained by the ERTS sensors
- Maintain photographic equipment.

3.2.1 Output Products

The standard outputs of photographic processing for dissemination to the users are:

- Black and white negatives
- Black and white positive transparencies
- Black and white positive paper prints
- Color positive transparencies
- Color positive prints.

Nonstandard outputs, in response to users' requests, may include:

- Black and white and color enlargements or reductions
- Glass plates
- Special color composites.

Other standard products include:

- Negatives and positives required in various processing steps
- Coverage montage negatives.

All standard black and white products for dissemination are on a 9.5-inch roll film or paper. Standard color transparencies are on either a 9.5-inch roll film or a 10 x 10-inch sheet film. Standard color prints are on 10 x 10-inch paper. Coverage montage dissemination products will be produced outside the facility to avoid the necessity of procuring and operating large lithographic presses.

3.2.2 Output Quantities

Production quantities for bulk modes I and II are listed in Tables 3-2 and 3-3, respectively. Quantities for precision modes I or II are listed in Table 3-4.

Table 3-2. Bulk Mode I Production Quantities

	Case A	Case B
Frames per day (7-day week)	315 (135/180)	1320 (495/825)
Sets per day (7-day week)	45	165
Sets to be processed per day	63	165
Bulk records (1N)	441 (375 ft)	1320 (1100 ft)
Copy positives (2P)	4410 (3750 ft)	13,200 (11,000 ft)
Copy negatives (3N)	4410 (3750 ft)	13,200 (11,000 ft)
Copy prints (4P)	4410 (3750 ft)	13,200 (11,000 ft)
Color negatives	39 (35 ft)	99 (85 ft)
Color positive transparencies	390 (350 ft)	990 (850 ft)
Color prints	390 (350 ft)	990 (850 ft)

Table 3-3. Bulk Mode II Production Quantities

	Case A	Case B
Frames per day (7-day week)	315 (135/180)	1320 (495/825)
Sets per day (7-day week)	45	165
Sets to be processed per day	63	165
Bulk records (1N)	441 (375 ft)	1320 (1100 ft)
Masters (2P)	441 (375 ft)	1320 (1100 ft)
Copy negatives (3N)	4410 (3750 ft)	13,200 (11,000 ft)
Copy positives (4P)	4410 (3750 ft)	13,200 (11,000 ft)
Copy prints (4P)	4410 (3750 ft)	13,200 (11,000 ft)
Color negatives	39 (35 ft)	99 (85 ft)
Color positive transparencies	390 (350 ft)	990 (850 ft)
Color prints	390 (350 ft)	990 (850 ft)

Table 3-4. Precision Mode I or II Production Quantities

	Case A	Case B
Sets per day (7-day week)	2.25	2.25
Sets to be processed per day	4	9
RBV masters (1N)	12 (15 ft)	27 (30 ft)
MSS masters (1N)	16 (20 ft)	36 (40 ft)
Copy positives (2P)	28 (25 ft)	63 (60 ft)
Copy prints (2P)	28 (25 ft)	63 (60 ft)
Copy negatives (3N)	28 (25 ft)	63 (60 ft)
Color negatives	12 (15 ft)	27 (30 ft)
Color positive transparencies	12 (15 ft)	27 (30 ft)
Color prints	12 (15 ft)	27 (30 ft)

3.2.3 Processing Modes

During each day of operation the sensor systems can produce a maximum of either 45 sets of images per day (Case A) or 165 sets per day (Case B). A set of images in Case A consists of three RBV frames and four equivalent MSS frames. In Case B a set of images consists of three RBV frames and five MSS frames (the fifth frame is the thermal infrared channel record). The imagery produced in Case A is processed by the NDPF in a 5-day, 40-hour week; processing of Case B imagery can reach a 7-day, 168-hour week.

Two processing loads have been established: 1) 100 percent of the images are processed in the so-called bulk mode; and 2) in response to user requests, an estimated 5 percent of the imagery is processed in a precision mode. In addition, color transparencies are produced from 20 percent of the bulk imagery and from all the precision imagery. Copies of the bulk imagery (negative and positive film and positive paper prints) are delivered to each of 10 users; copies of precision imagery are delivered to the requesting user.

3.2.4 Quality Assurance

The data services photo laboratory establishes and maintains densitometric/sensitometric and chemical analysis procedures which

assure the utmost in quality control. The basic precept ensures that any differences in tonal or spectral responses in the photographic materials can be attributed only to differences in the ground scene, the illumination, the atmosphere, or performance of nonphotographic elements of the ERTS system.

Sensitometric step wedges are exposed on the head and tail of each roll of film to be exposed and developed. Following development, these wedges are read on a recording densitometer which automatically produces a sensitometric curve. Experienced operators can determine from this curve the nature and magnitude of changes that must be made in the exposure or chemical processing of the film.

Similarly, sensitometric tests are made when raw film of a new batch number is received. These tests are made by exposing a step wedge on a sample of the new film, processing the sample in a sensitometric processor, reading the wedge on a densitometer, and converting the resultant sensitometric data into modifications of the printing and processing procedures for film of that batch.

Analyses of all chemical solutions are performed in the mixing room before the mix is certified for use. Samples taken from the processing machine during a run, and especially prior to starting up after a prolonged shutdown, are also analyzed. The principal tests assure standard pH, bromide content, and total alkalinity of the solutions. Special tests may be run to determine causes of unexpected film response.

The processing machines are scratch-tested and chemically certified at the beginning of each day, or following a prolonged shutdown. The scratch test involves running a strip of fogged film through the processor and examining it for scratches or abrasions that might be caused by a buildup of foreign materials (e.g., dried gelatin) on the rollers. The chemical certification involves processing a sensitometric strip in the machine and reading the results on a recording densitometer.

The processed film is cleaned and waxed on a Kodak Model JB-CW2 waxer before it leaves the processing section. This is especially important in the case of archival materials and of positives or negatives

that must be used several times in a printer as, for example, in the exposure of 10 duplicates from a single film.

In the final inspection section, the photographic products are visually inspected (Richards light table, Bausch and Lomb Zoom 70 stereomicroscope) for quality and for adherence to the work order. Defective materials are recycled to produce acceptable delivery products.

3.2.5 Tonal Reproduction

The transfer of information through an imaging system, whether it is a photographic, electronic, or direct viewing optical system, is accompanied by finite degradation of the information content. In many imaging systems, the quality criterion is that the imagery be pleasing to the observer. Those qualities that present a pleasing apperance are determined by the characteristics of tonal reproduction, sharpness (as contrasted with resolution), and, in color reproduction systems, the color balance or fidelity both in hue and purity. In general, it may be said that a pleasing reproduction of a scene is one that the observer feels is a reasonable likeness of the original.

For scientific work, the criteria are more stringent. The data received from the imaging system must be capable of interpretation with precision and repeatability with regard to position within the image field (geometry), intensity of the reflected radiance with regard to object characteristics, both spectral and intensity, and the characteristics of the radiating source, modified by the characteristics of the transmission path (atmosphere, radiometry). It is also necessary that the edges of objects seen in the image be sharply defined.

The term gamma, from its origin in photography, denotes the slope or gradient of a characteristic (D-log E) curve plotted on log-log paper. For signal changes of a small percentage, the value of gradient or gamma is the ratio of relative output to relative input. For example, when a gradient of 2.0 is specified for a given point in the characteristic curve, it means that a 2 percent change in input will cause a 4 percent change in output. If the characteristic curve that describes the dynamic transfer function of log radiance input to log radiance output were a straight line,

the gamma would be a constant at all points. This does not occur in practical systems, so that gamma refers only to the slope of straight line portion curve. The term gradient is applied to describe the derivative of the curve at all other points.

Thus, the measure of gamma is a measure of the enhancement or reduction of contrast of a reproduction relative to the original. If the gamma is greater than unity, contrast differences in the object are increased in the reproduction. If gamma is lower than one, contrast is reduced. When gamma is unity, the reproduction system is linear.

The characteristic curve of practically all image reproduction systems is S-shaped so that the gradient in the low-light, or toe, and the high-light, or shoulder, of the curve is considerably less than the maximum gradient or gamma that is measured in the middle of the curve. This lowering of gradient causes a compression of grey step values at these points. Generally this is considered beneficial since it permits fitting a relatively large input dynamic range into a somewhat more restricted dynamic range of the reproducing system.

A multispectral acquisition system provides a means of enhancing differences in recorded imagery by breaking the spectrum of an object into several component bands. This allows increased information discrimination. Tonal differences that may exist in narrow spectral bands are often masked when integrated over a broad spectral range. For a multispectral band acquisition system, the system should be balanced to acquire the maximum amount of information discrimination in each individual band.

The ERTS system utilizes tonel change detection to enhance the ability to detect and recognize earth resources information. Since multispectral change detection is the main goal, the system must be precalibrated for maximum information extraction for nominal image acquisition conditions. Once these conditions are established they are fixed, and at least in bulk mode reproduction will represent the same system parameters. In this way, any tonal or color changes in the final output imagery will reflect changes in either the satellite sensor, telemetry, or

reproduction systems. In special cases, such as in the precision mode, it may be advantageous to deviate from this fixed tone reproduction standard to enhance certain image properties at the expense of others.

Because of atmospheric attenuation and scattering, one would expect the dynamic range of the multiband records to be different. Atmospheric scattering, often referred to as haze or atmospheric radiance, is basically a wavelength-dependent function and varies from being completely selective to being almost totally nonselective depending on the types and concentrations of particles in the atmosphere. For a pure Rayleigh atmosphere, the scattering is inversely proportional to the fourth power of wavelength. For a hazy atmosphere with large concentrations of water vapor and smoke, the scattering is almost wavelength-dependent. Some authorities have stated that a typical atmosphere combining both Rayleigh and Mie scattering goes approximately as a function inverse to the 1.6 power of wavelength. In any case, the nominal conditions for scattering are predominantly in the ultraviolet and blue region of the spectrum and fall off significantly as one goes to the red and infrared regions of the spectrum. For the ERTS case, one would expect the apparent contrast in the red band to be higher than that in the green, and that in the infrared to be higher than that in the red.

Test results at Itek have indicated that optimum results are obtained when the density ranges of the individual spectrum records are approximately equal. If the densities of the records are equivalent, the printing and color balancing of the resultant additive color records are simplified. A nominal dynamic range on the order of about 10:1 (equivalent to a density range of 1.0) has been found to be ideal for making additive color records. Most color reproduction materials have a fairly high gamma with a relatively narrow exposure latitude. Too high a contrast in the separation records can result in a loss of information because the color reproduction material is not able to record the entire tonal range of the input imagery. The density range should also be kept down because it makes exposure and color balancing easier in the additive color process.

The individual separation records can be dynamically balanced to some extent either in the satellite or in the ground handling equipment.

Some correction may be possible in the satellite by adjusting the gain control on the individual RBV cameras. Thus, it may be possible to telemeter equivalent signal ranges for each RBV. This will have the effect of altering the apparent scene contrast range in one or more of the records to produce a near balance. This would be done in a calibrated fashion so that the actual apparent object radiance could be reconstructed if desired. Once this calibration is set, the RBV responses should not be changed during the life of the system. Uncontrollable system changes that result from aging and temperature variations can be determined by calibrated reference standards within the satellite.

The input dynamic range can also be altered in the initial printout state. Here the taped input data for each channel can be computer analyzed and a corrected signal can be fed to the laser beam recorder. In this manner, the dynamic range for each record can be either raised or lowered to a prescribed level to produce a nominal standard equivalency. Again, once this condition has been established for the bulk mode, it should remain constant.

For the precision mode, one might want to deliberately deviate from this standard. For example, there might be three possible atmospheric conditions, heavy haze, moderate haze, and clear. Specific precalibrated correction functions could be stored in the computer for these three cases. The computer would input these specifications to the laser beam recorder to balance the dynamic ranges of the individual records for each specific condition.

A third possible way to correct the contrasts of the multispectral black and white records is by processing each individually to different gammas. However, this is not recommended, since the control and repeatability of such a process would be a complex process with a high potential error. The major tone reproduction corrections should be made in the computer and laser beam recorder stages of the reproduction process.

Photographic experience has shown that in multiple duplication stages, best results are produced with a process gamma of 1.0, at which

there is a 1:1 correspondence between log exposure range and density range. Once the film type and processing conditions have been established to achieve the optimum nominal condition, they are held constant to ensure repeatable results in all future reproductions.

A calibrated reference step wedge is generated in the laser beam recorder. This provides the best process control and color balancing of the imagery. This step wedge is used as a process control standard for subsequent production stages. By monitoring the densities reproduced on the wedge, proper exposure and photographic processing control can be assessed. The three integrated calibrated step wedges on the RBV records should produce a neutral black and white tone. Deviation from a neutral tone would indicate an improper balancing of one or more of the multi-spectral print channels used to produce the additive color record.

Neutral tone balancing has been used as a standard in color printing for many years. In multispectral cases, balancing to a neutral tone for certain types of images may not produce optimum results. In the precision mode, the balance may be altered to produce records that meet the optimum needs of a user.

3.2.6 Radiometric Accuracy of a Photographic Process

Since the ERTS imagery extracts radiometric data from the ground scene, it is necessary to consider the accuracy of photographic materials used as quantitative radiation sensors. A well-controlled photographic process can produce remarkably accurate and repeatable radiometric and photometric data.

Several types of errors can occur when film is used as a radiometer. The first error is caused by the nonuniformity of sensitivity in the typical photographic material. Any nonuniformity in sensitivity across the film web will produce errors in the developed imagery. However, the uniformity of the quality films made today is exceptionally good, and sensitivity variations are less than 5 percent as a result of manufacturing tolerances. As long as the film is stored in a suitable environment, which it will be, uniform sensitivity is maintained until the film is used. The absolute sensitivity of photographic materials can vary with each

batch. However, batch variations can be determined and corrected in a quality-control sensitometric operation so that essentially uniform results can be obtained from batch to batch.

The largest radiometric error generally occurs in film processing. To achieve good radiometric results, the uniformity of the processing is well-controlled. Each part of the film receives the same chemical treatment. This requires uniform agitation and uniform temperature as well as constancy of developing solutions. Processing uniformity on the order of 95 percent or better can be achieved in precise sensitometric processing. Variations are those across the format and not the point-to-point variation between adjacent detail.

The size of the object or objects being evaluated influences radiometric accuracy. Photographic film is composed of small grains of silver. These grains represent the noise in the photographic process. When a large area is being evaluated, it is well above the noise level of the system and the radiometric accuracy is quite good. However, as the objects being evaluated become smaller, the grain noise of the system and density fluctuations as a function of this grain noise begin to appear. The film that has been selected for ERTS duplication, EK-2430, has the lowest granularity (8.9) of currently available production duplicating materials, and it will have a minimal effect on the radiometric accuracy of the system.

Exposure variations also affect photographic materials used as quantitative radiation sensors. However, quality printing devices assure exposure accuracies of within a few percent. The possible reciprocity effect that results from large exposure variations could cause error, however, extraordinarily large ranges are not required in the ERTS application.

Latent image decay is another potential source of radiometric error, but significant time lags between exposure and processing do not occur in the NDPF design.

3.2.7 Image Quality

To produce the output photographic product with a minimum quality degradation through the number of required image generations, the NDPF

employs 9-1/2 inch film at each step in the process. The images on the 9-1/2 inch stock are 7.3 inches square which represent a linear magnification of 7.3 over the RBV format. Considering that the RBV response is not over 80 lp/mm, the NDPF equivalent performance must be on the order of 10 to 11 lp/mm.

A Kodak type 2430 fine grain duplicating film is used for all duplications. This film has a resolution capability of over 300 lines pairs per millimeter, and its transfer function is high. At the nominal resolution for laser beam recorder imagery, i.e., 10 cycles per millimeter, the MTF of this film is approximately 0.95. If the MTF's are cascaded, the system modulation can be calculated through a number of generations, using Type 2430 film in each of the reproduction stages.

Three duplication steps are required to produce the final dissemination black and white transparencies with a resultant modulation transfer response of 0.86. Using Type 2430 film at this modulation transfer results in very little loss.

The anticipated quality of the false color prints and transparencies that will be produced from the black and white spectral records should also be considered. It has been theoretically and practically demonstrated that by superimposing identical images, i.e., images whose geometry is intrinsically the same, one can effect an enhancement in image quality. If multiple images were reproduced and integrated by superimposing on black and white film, the resolution of the resultant print would increase as the square root of the number of integrations. This is accompanied by an increase in edge definition.

When a color material is used to record the integrated records, the results are less straightforward because the images do not truly integrate, being formed on the three emulsion layers. However, since part of the addition is due to hue and color differences, there will be some degree of image enhancement, especially in areas that reproduce in a more or less neutral tone. Thus, even though the image quality of the color reproduction material is intrinsically lower than that of equivalent black and white duplicating materials, the resultant color imagery should be equivalent or superior in usefulness to black and white imagery.

3.2.8 Photographic Printing

To produce film and paper copies of RBV and MSS imagery for distribution, continuous printers capable of exposing approximately 8000 feet of film and 4000 feet of paper per shift are required. The Log-Etronic SP-10/70 is capable of reproducing 200 lines/mm and has a variable throughput rate that depends on the density of the input negatives and on the output material. It is estimated that an average rate of 25 feet per minute for film and 15 feet per minute for paper can be achieved. Thus, two Model SP-10/70's are required to expose either Case A or Case B copies. The estimated capability of two printers exceeds the throughput requirements, thus providing a backup capability for peak loads and/or machine downtime. The SP-10/70 is relatively simple to operate and maintain. The electronic circuitry is modularized so that most breakdowns can be rapidly corrected by exchanging plug-in components. As with any printing device, the SP-10/70 is sensitive to vibration. However, suitable damping mounts minimize this problem.

The imagery from the seven or eight RBV and MSS sensors is recorded first by a laser beam recorder. In bulk mode I, the bulk record (1N) is printed on the SP-10/70 to produce 10 copies of the 2P positive transparencies and the 2P paper prints. The 2P transparencies are printed to produce 10 copies of the 3N. The film transparencies (positive and negative) are reproduced on Kodak Type 2430 film. The paper prints are made on Kodak varicontrast waterproof paper. The exact exposure parameters are determined initially during the prelaunch integration and acceptance period. Adjustments are made during the immediate postlaunch period, based on sensitometric/densitometric tests.

The printing process in the bulk mode is not allowed to cause uncontrolled variations in the tonal reproduction process. The inherently high (99 percent or better) MTF of the contact printing process ensures that the only loss in resolution from generation to generation is that caused by the MTF response of the films. Losses in resolution that are inevitable in optical (i.e., enlarging or reducing) printing are avoided.

In the precision (request) mode, it may be desirable to deviate from the standard printing process to provide separation negatives and/or

positives especially designed to emphasize features of interest to the user (e. g., to alter the maximum or minimum density or the gamma of a specific spectral record to emphasize geological, agricultural, or hydrographic features in an area). Experimentation in the photographic laboratory will be necessary to establish the nature and magnitude of required deviations from standard procedures. Especially exposed films are made on either the Log Etronic SP-10/70 or on the Miller Holzwarth 1119; the latter being used to satisfy most special request printing. The 1119 is a manual "one-at-a-time" printer with excellent resolution (approximately 200 lines/mm). The output film is in the form of 10 x 10-inch sheets.

In addition to contact prints (on film or paper), users may request enlargements of all or portions of a frame or set. A Durst V-184 enlarger has been selected to satisfy this requirement. The Durst has a resolving power of about 100 lines/mm. A complete set of lenses and condensers is provided to permit enlargements of 10 x 10-inch negatives up to 20 diameters.

Two Miller Holzwarth Model 1119 contact printers are provided. This is a step and repeat (i. e., noncontinuous) printer. It accepts sheet or roll film input and output materials. It is a point light source printer and is rated at 140 lines/mm at 2:1 test object contrast. Variable contrast filters are provided for use with variable gamma paper, or with panchromatic film. Dodging is provided by a system of adjustable mirrors. The printer is equally usable for black and white or color printing.

A Morse Model A-14 contact printer is provided in the montage darkroom for exposing the reduced copy negatives made from the 7.3 x 7.3 inch prints. This is a noncontinuous sheet paper printer of adequate resolution.

3.2.9 Film Processing

Approximately 8000 linear feet of film and 4000 feet of paper will be developed in an 8-hour shift (either Case A or Case B). Developing equipment to handle this quantity of film was selected by analyzing throughput time, simplicity of operation and maintenance, proven ability

to produce high quality output, initial cost, and availability. The Kodak Versamat Model 11-CM was selected.

The Versamat is simple to operate and maintain. However, it must be carefully prepared for use and, even more important, must be cleaned thoroughly when it is to be shut down for any appreciable period. It is self-threading, and accepts film or paper in short lengths (as small as 4 x 5 inches) or rolls up to 1000 feet long. Environmental and utilities requirements are minimal.

A nominal throughput rate of 15 FPM and an operating period of 6 hours per 8-hour shift is a realistic planning figure. This equates to 5400 feet of film per machine per shift. Each shift is required to process approximately 8000 feet of film and 4000 feet of paper. Three Versamats are required to accommodate this workload. A fourth Versamat has been included to handle peak workloads and special requests, and to serve as a backup in the event of malfunction.

Several chemistries are available for processing film in the Versamat. Itek's proprietary PC-5 chemistry, developed especially for use in the Versamat, appears to be superior to chemistries offered by other vendors. This is based on the extended dynamic range of imagery developed in PC-5 faster throughput time, lower replenishment requirements, and suitability for use with almost any silver halide film or paper. A final choice of chemistry will be based on tests conducted in which imagery closely resembling that expected from the laser beam recorder and precision photo restitutor is processed.

The chemical solutions used in the data services photographic laboratory are prepared in a chemical mixing room suitably sealed from the rest of the facility to preclude contamination of the air by chemical dust. Solutions are prepared in transportable 50-gallon mixing tanks. Waste solutions are piped to a central location for recovery of silver and treatment prior to being discharged into a sewer system.

3.2.10 Color Reproduction

Color composites made from ERTS imagery do not necessarily reproduce the visual appearance of the colors in the scene. The spectral

bands do not coincide with those used in normal true-color photography. The purpose of the ERTS color photos is to provide the user with an image in which the color of an object provides some desired information about the object. The process of producing a color composite must therefore be designed to record spectral signatures as they are seen by the ERTS sensors, and as they are recorded by the laser beam recorder on black and white color separation negatives.

In normal color duplication processes, rather elaborate precautions are taken to correct the color balance, contrast, and density. These precautions are of lesser importance in producing color materials from the ERTS imagery. In fact, it is probably not desirable to introduce into the processing cycle any of the techniques used to correct the colors in the conventional process. This statement is based on the premise that the hue and chroma of the final color reproduction is unimportant; what is important is that any given color of an object always mean the same thing about the object, or conversely, that a given object condition should always reproduce as the same color.

This establishes the requirement that each step in the color process must always convert the same combination of black-and-white tones (in the black and white separations) to a specific color in the final composite color transparency or print. In order to achieve this end, several precautions must be taken, and each step in the color process must be standardized. The necessary precautions are:

- The black and white separations must be exposed and processed to produce densities and contrasts which characterize the reflected illumination from the scene as modified by the atmosphere and the transmission/recording system.

- The composite color materials must be exposed by illumination of standard color temperature and intensity for a standard exposure time.

- A standard set of filters must be used during exposure of the color negative.

- The color film or paper must be calibrated against a standard negative, and color correction filters must be selected which assure a standard response when the preceding precautions have been observed.

- The color materials must be stored and otherwise handled in such a manner that temperature and other variables do not alter the color response.
- The time between exposure and processing should be as nearly uniform as possible.
- Processing must be standardized.

The production of composite color negatives from black and white separation positives or negatives involves the additive color printing process. In this process, a single sheet of color film is successively exposed by blue, green, and red light modulated by the corresponding black and white separation films; exact registration of the three exposures is mandatory. (Special effects may be produced by varying the combinations to filter and separation image. For example, it may be desirable to modulate the blue light with the red record and vice versa to accentuate some feature in the imagery. It may also be desirable for some special cases to use a negative separation for one color and positives for the other two.)

The following filters are the standard filters used in additive color printing: Wratten No. 25 (red), No. 99 (green), and No. 98 (blue). Neutral density and color correction filters may also be required to modify the exposure and to balance the color material to the standard.

Tungsten operating at 3,000°K produces the desired energy levels with adequate evenness of intensity distribution. The Sylvania BVA and FCS tungsten halogen lamps are more than adequate to produce the energy levels required within the desired spectral regions. The extra energy produced by both lamps allows any future changes in the system to be readily made.

In all three-color systems, a certain ratio of energy inputs to the three sensors is specified as neutral or grey. As the intensity of the input energy is increased while the specified ratio is maintained, the luminance of the reproduction increases (lighter greys) toward white. A change in the ratio produces color. Adjustments of the three RBV camera systems to maintain grey-scale tracking over the range from black to

white is critical if spectral signatures are to be reproducible in the false-color hard-copy output of the system.

Nonlinearity of the responses of each camera and associated video amplifier and differences in black-level setting affect the tracking capability of a three-color vidicon camera system. If the system is adjusted for correct tracking of large area grey steps, errors in small area grey steps at the black end may still exist because of flare light addition. Since the photo-conductor of the vidicon may exhibit increased transparency toward the red end of the spectrum, this flare increases for the red as compares with the blue-green. Before flight, the RBV system must be calibrated for black level shifts in small area blacks as a function of the average irradiation reaching each sensor. Some correction can be made in the image recorder by resetting the black level of the recorder for each spectral band.

The color control system is based on the use of one or more standard negatives. These negatives include imagery typical of the scenes to be photographed by the RBV and MSS, both as to terrain and color. A neutral grey area is included on each negative. One negative is the primary control for calibrating new color materials; the others are secondary controls for special lighting, terrain, or other conditions. The control negatives are used: 1) for comparing printing characteristics with those of other color negatives, 2) for comparing the color responses of different emulsion coatings (batches), 3) for checking processing, and 4) for determining which color correction filters are required in the printing process.

An additional control will be available in the grey scales exposed on the separation negatives in the laser beam recorder. The densities of the grey step on each separation corresponding to the grey area of the control negative will be read. These are used, in conjunction with red, green, and blue, densities of the grey card on the control negative to determine the cyan, magenta and yellow filters necessary for accurate color rendition.

The color reproduction system is based on the Kodak Aero-neg system. The basic elements of this system are shown in Figure 3-13.

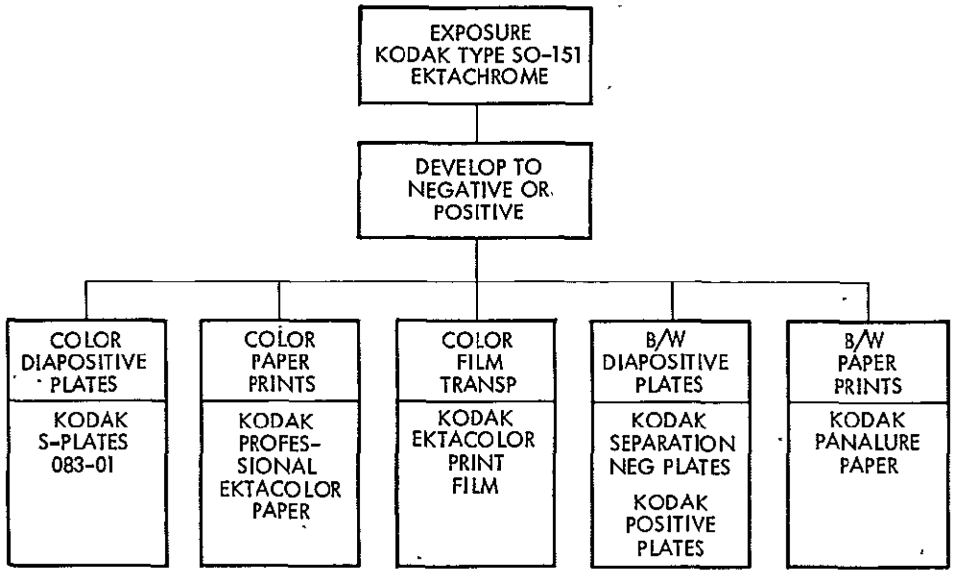


Figure 3-13
KODAK AERO-NEG color system

The Aero-neg system is selected because of its versatility and the ready availability of sensitized materials and chemicals.

A manual method of producing color negatives is available and adequate. It consists of the following steps:

- The three-color separation positives are visually registered on a light table, using the registration marks produced by the laser beam recorder. After registration, the positives are taped together.
- A Condit registration punch is used to punch two holes simultaneously in the border of the three registered separations.
- In a darkroom, a sheet of color film is placed in position on a Condit registration board. One of the three separations is placed in contact with the film. The registration board provides two pins carefully matched to the holes produced on the registration punch. An exposure is made through the separation positive; the illuminant is a point-light source with an appropriate filter.
- The first separation is removed, the second is positioned on the registration board, and an exposure is made through an appropriate filter.
- The third separation is similarly exposed.
- The color film is developed to produce a positive or negative transparency, which is then used in a color contact printer to produce copies.

Tests conducted on a Kodak registration punch and registration board, which have been in use for several years, have shown that registration is achieved to within 0.0005-inch.

The color negatives produced manually are processed in a Carr Model 195-2WM color processing unit. Contact prints are made on a Miller-Holzwarth Model 1119 printer. A Kodak Model 16K rapid color processor is provided to handle special request or small quantity color paper processing. A Macbeth Model EP-1000 color analyzer is provided for use in maintaining color balance in the color materials.

The precision photo restitutor can also produce false-color negatives, providing by this feature a peak-load backup. The steps are as follows:

- A color separation negative is positioned on the input stage, and unexposed color film on the output stage. The precision photo restitutor is operated in the noncorrelation mode and the image of the input negative is exposed (through a color filter) on the output film.

- The second separation negative is positioned on the input stage and exposed through its filter, in precise registration with the previous image. The third separation is similarly exposed. The output film is not moved until all three images have been exposed.

- The color film is developed to a negative by reversal if the inputs are negative, or it is developed directly to a negative if the inputs are positive.

A Log-Etronic color printer Mark III was selected for exposing color transparencies and prints from the color negatives. This instrument is widely used by aerial photography firms and is readily available. A competitive instrument, the Kodak Rainbow, was rejected because of cost and long procurement lead-time.

Several continuous color developers were considered for the data services photographic laboratory requirement. A color Versamat Model 1411 was selected because of its established reputation and also because of commonality of parts with the black and white machines. Only one color Versamat is required to satisfy the throughput requirements. Either roll film or sheet film may be processed on this instrument.

Similarly, the Versamat will accept either film or paper without a change of chemistry or other major operational adjustments.

Shading-variations that are acceptable in black and white reproduction may not be acceptable in a three-color system. Differences in the responses of the three RBV tubes as a function of position on the photoconductor when exposed to a uniform spectrally neutral field may cause noticeable departures from neutrality in the reproduction when printed onto color material. Variations noticeable as color shading of reproduction of a grey field will indicate the need for further shading correction beyond the correction that is inserted in each RBV camera system. If this is a problem in the ERTS color reproduction system, correction may be applied by using positive silver masks in the duplication stage, or by dodging. (Both the Miller Holzwarth 1119 and the Log-Etronic Mark III have this capability. The 1119 uses a set of adjustable mirrors; the Mark III uses incremental exposure control.)

3.2.11 Coverage Montage

The principal map series that covers the U.S. at a scale of 1:1,000,000 are the World Aeronautical Charts. More than 50 of these charts, each 22 by 29 inches, are required to cover the U.S. and Alaska. The mechanical difficulties of producing the montages on these charts discourage their use.

The Geological Survey map of the U.S. is a single sheet, 42 x 65 inches, on a Lambert conformal projection, at a scale of 1:3,168,000. The map contains the outlines of the individual states, the locations of major cities, and the major drainage systems. It appears to be the best choice for the montages in order to minimize production problems (especially in view of the requirement for 1,000 copies of the montage).

The photographs are reduced from 7.3 by 7.3 inches to approximately 2.27 x 2.27 inches to conform to the map scale. Prints at 1:1,000,000 (made from the bulk processed negatives) are affixed to a baseboard (matching detail in the 10 percent overlap), and copied on an 8 x 10 inch film sheet. Three sets of four prints may be copied on one 8 x 10 inch negative. As many prints as necessary for an orbit are copied

in this manner. The negatives are contact printed. After the prints are trimmed and affixed to the base map, matching detail to the map and to the overlap, the montage is recopied at a reduction of approximately 2.7x. Four 20 x 20 inch negatives are required to include the entire map with a 1-inch overlap between the negatives, both vertically and horizontally.

When the resulting negatives are reproduced by photolithography at a 1:1 scale, the images of the ERTS photographs are slightly less than 1 x 1 inch. Although the individual frames are quite small, it is possible to annotate each frame with an identification legend that will enable the user to determine the identity of any frame he wishes to retrieve for special processing. As an adjunct to the montage, a textual description (date, time, and sensor) of the frames available in each pass will be produced to supplement the annotation of individual frames.

NASA specifies that separate montages are to be prepared for the RBV and the MSS imagery. This may not be necessary to provide information regarding coverage by either of the two sensors (except possibly coverage by the thermal infrared channel of the MSS). If coverage of an area is available from both sensors, only one RBV frame is needed to prepare the montage. If either sensor were inoperative, or if the imagery of one sensor were lost in the transmission or recording processes, a single letter code on the montage print or in the textual data could indicate the operational sensor.

Reproduction of the montages should be accomplished by the Government Printing Office or by some other agency equipped to reproduce large cartographic products. This would obviate the need for the NDPF to procure and operate large lithographic presses and ancillary equipment that would be used only twice monthly. The montage pages should also be bound by this reproduction facility.

3.3 PCM TELEMETRY AND DCS PROCESSING

3.3.1 PCM Processing

The processing of PCM telemetry consists of five procedures:

- PCM preprocessing
- Attitude determination

- Annotation tape generation
- Master digital tape generation
- PCM data base generation.

3.3.1.1 PCM Preprocessing

The PCM preprocessor verifies and/or corrects the GMT assigned to the PCM data, extracts camera exposure times, merges orbital parameters and creates the initial spacecraft reference tape.

3.3.1.2 Attitude Determination

The attitude determination function determines the attitude of the spacecraft, creates the attitude history and merges the attitude data with the corrected time and orbital parameters, creating the final spacecraft reference tape.

The two resolution accuracies specified for ERTS require two levels of spacecraft attitude determination. The first level, applicable to the coarse resolution accuracy of 10 nautical miles, is achieved by directly reading and smoothing the appropriate data from ERTS telemetry tapes (i.e., pitch, roll, and yaw error signals). The second level of attitude determination is applicable to the fine resolution accuracy of 2 nautical miles and is achieved by optimally filtering all available telemetry data over wide time intervals to update and improve spacecraft attitude estimates.

This function (see Section 6) accepts processed telemetry data and, after editing, proceeds to smooth the pitch, roll, and yaw data with a sliding arc second degree polynominal. Outputs are obtained at the midpoint of the smoothing interval, thus providing the first required level of attitude determination.

The second level of attitude determination is based on a realistic model of spacecraft attitude dynamics coupled with a direct-search optimal filtering function. The attitude dynamics program generates; by numerical integration of the complete (non-linear, coupled) attitude equations of motion, a set of ERTS pitch, roll, and yaw trajectories based on an initial attitude state and nominal values for several model parameters whose exact values are not known. At each observation time,

computed values of observables are obtained from the results of the numerical integration; a quadratic cost function is then formed and the direct-search program proceeds to systematically adjust the initial attitude state and model parameters until this cost function is minimized. The direct-search program is based upon Powell's direct search algorithm for numerical optimization of a function of several variables and uses built in logic to obtain the optimal estimation of attitude state,

To insure accurate and realistic data fits, all known disturbances and error sources are to be included in the attitude dynamics model. Thus, specified thermal deformation effects, sensor misalignments, and sensor biases are to be incorporated (depending upon degree of uncertainty) with an adjustable parameter.

The attitude state (angle and angle rates) required to initialize the attitude dynamics model is obtained from the smoothing function (digital filter) previously described. Additional data (e. g., wheel speeds) required to initialize the attitude dynamics model are received directly from the processed ERTS telemetry. Spacecraft orbit data, solar ephemeris, and a model of the earth's magnetic field are also necessary to calculate all position-dependent disturbance torques.

The observables for the direct-search filtering consist of onboard-acquired (unsmoothed) pitch, roll, and yaw angles; wheel speeds; solar array shaft angles; onboard solar sensor data; and ground truth data. Coalescing all such attitude-dependent data into the direct-search procedure will yield the desired highly refined initial attitude and model parameter values necessary to obtain a definitive attitude history from the attitude equations of motion.

3.3.1.3 Annotation and Index/Abstract File Generation

The annotation and index/abstract tape generation function generates the annotation data required by the bulk image processing function, and the initial entries in the index/abstract file. The following data appear on the annotation tape:

- Coordinates of subsatellite point
- Acquisition site

- Principal point-image UTM coordinates
- Meridian divergence
- Tick mark location and label 1 through n
- Identification code
- Processing code and data
- UTM zone
- Reference marks 1 and 2.

Index data about the geographic locations of the images are generated for subsequent input to the index/abstract file. The following data appear on the index tape:

- Orbit number
- Date
- Time of exposure
- Calibration image
- Center coordinate of image
- Four-corner coordinates of image
- Sensors
- Spectral bands
- Heading angle
- Turn angle
- Altitude
- Roll, pitch, yaw
- Cloud cover (added by operator)
- Snow cover (optional)
- Image quality (added by operator)

These data are computed from the output of PCM preprocessing and attitude determination using a "vector method."

3.3.1.4 Master Digital Tape Generation

Generation of the master digital tape consists of the merging of all time, orbital, attitude, and spacecraft performance and status data onto a single source for future retrieval. Attitude history data, originally considered as a separate data file, is stored on the master data tape.

3.3.2 DCS Data Processing

DCS data are received in the NDPF in digital form, where each message is verified, identified, corrected, and reformatted as to its source and content. Time corrections are made, when necessary, and the DCS tape is created. Each day's DCS data tape is further processed as an information file by forwarding it for data file maintenance. It is provided to the users in the form of listings, digital tapes or punched cards, as required.

3.4 NDPF OPERATIONS

3.4.1 NDPF Products

The daily activities of the NDPF revolve around production of both standard and special products, and the maintenance of all data in archives, indexes, hard-copy libraries, catalogs, etc. Standard products are primarily the result of the bulk processing mode of operation (a normal 18-day coverage cycle), and include both data processing actions and photo laboratory services:

Data Processing	Photo Services
RBV/MSS coverage indexes	Montage catalogs
Abstract catalogs	Master negatives
DCS tapes	Positive transparencies and prints
Digital imagery	Registered/unregistered imagery
Spacecraft performance tapes	
Management control data (internal)	

In addition to the standard ERTS products there are a number of special products which are the result of user requests and can also be classified as either data processing oriented or as imagery.

Data Processing	Photo Services
Miscellaneous query retrievals (coverage)	High precision imagery
Special listings (spacecraft, ground reference)	Color composites
Special catalogs (abstracts)	
Digital image tapes	

Providing the users with special data processing products (query retrievals, listings, etc.) is also a normal function of the NDPF, revolving around the generalized information management capability. This provides the users with a convenient data exchange and inquiry service allowing a common input mode to all data files. Most user requests for other than imagery will be accommodated by this service.

3.4.2 Information Management

The ERTS will produce significant amounts of data including multispectral imagery, spacecraft performance, orbit and attitude, and environmental data from automatic ground sensors. This data must be organized so as to be readily processed, maintained, and accessed. To this end, a set of data files have been specified. Based on the structure and organization of these files and the processing and management program, a flexible and responsive data processing capability is provided.

Inputs to the NDPF files comes from PCM telemetry processing, the production control system, post-processing of imagery within the NDPF, and abstract data from users. All inputs and outputs from these files are via the information management program except for some specialized files in the telemetry processing area.

3.4.2.1 Data Files

The set of required files consists of those that process user-oriented information and internal files which are needed in some data processing functions to develop desired system and user file capabilities. A description of these files and their use in the NDPF follows.

Index/Abstract File

This file provides an index to all RBV and MSS imagery processed and stored within the NDPF. This includes all corrected, precision

processed, and color composite images generated in the NDPF. All content data (i. e., abstracts) about the imaged area that is supplied by the users is contained in the file. The index portion of this file contains the necessary annotation data for later processing of RBV and MSS imagery.

The file is structured to handle fixed data such as the index, and variable data such as the abstract portion of the record. The file is stored on a disk for use in a direct access device. In operation, index information is generated in the PCM processing phase and passed on to the information management program. This program updates the file with new information. For instance, after the imagery associated with the index is automatically processed, the photography is screened for quality, cloud cover, and later for data content by users. Using an interactive display terminal, the operator calls in the index for that set of images, displays them on his screen, and updates the index. In an alternate mode of operation, the new data is written on a form which is keypunched and placed in the file at a later date.

After a complete day's take of imagery is added to the file, a retrieval is run against the file to output the data and prepare a listing to be shipped to the users with the film. The users also receive an abstract form which has been automatically prepared with image identifying information and with room to add descriptive detail about the contents of the image. The abstract form is structured to control the format of the data generated by the user. The user returns this form and the new abstract data is keypunched and added to the file.

Every 18 days a retrieval and output of index/abstract data for that period is made and sent to all users with themontage catalog. The file is also queried to provide the basic and major portion of annotation data for annotating imagery which has been corrected or generated later within the NDPF. The file is also used to satisfy user requests for imagery over a geographic point, line, or area and for abstract data based on keywords, descriptors, and attributes.

RBV and MSS imagery is indexed and abstracted on the basis that one record will be generated for a combined set of RBV and MSS imagery

taken at the same time and imaging the same area in the 100 by 100 nautical mile image area. This structure includes the capability to handle those times when imagery is obtained from only one sensor. The data content of the index portion of the record is:

- Orbit number
- Data
- Time of exposure

(Orbit number, Data, Time of exposure: Record control)

- Center coordinate of image
- Corner coordinates 1 through 4 of image
- Sensors
- Spectral bands
- Heading and sun angles
- Altitude
- Roll, pitch, yaw
- Cloud cover and snow cover (optional)
- Image quality
- Special processing

  Bulk corrected - color composite
  Precision processed - color composite
  Color composite

Data content of the annotation portion of the record is

- Coordinates of suborbital point
- Acquisition site
- Principal point-image UTM coordinates
- Meridian divergence
- Tick mark locations 1 through 5, Labels 1 through 5
- Tick mark location n, Label n
- Identification code
- Processing code and data
- UTM zone
- Reference marks 1 and 2

Data content of the abstract portion of the record is:

- Discipline
- Subdiscipline

- Keywords - category
- Attributes - type
- Modifiers - descriptors

The size of each record varies depending upon the amount of data abstracted for a combined image set. The average record size is 500 characters.

Using image acquisition rates of 45 sets per day for Case A and 165 sets per day for Case B, the yearly amount of new data generated for the index/abstract file based on a 5-day week and assuming linear growth is:

Case A: 8.2×10^6 characters

Case B: 30.0×10^6 characters

Some of the features and capabilities of this file, in conjunction with the information management program are:

- Display and update at a terminal
- Automatic indexing of new photography
- Batch updating with user abstract data
- Fixed records and subrecords and variable data
- Geographic retrievals - point, circle, polygon
- Retrievals using Boolean logic and English-like statements
- Standard data catalog of all index/abstract data generated over an 18-day complete U. S. coverage period
- Specialized output capabilities in response to user requests.

Master Digital Data File

This file provides a history of all PCM housekeeping telemetry that has been time-corrected, and also has been merged and correlated with the corresponding orbital and attitude data. The major use of this file is for analysis of the health of the ERTS spacecraft and its sensors.

Data for this file come from different sources. PCM housekeeping telemetry is received at the tracking stations where GMT date is attached

to each telemetry frame of data. These data are then sent to the OCC where they are verified and digitized. Orbital data come from the STANDAN/MSFN networks. The processing, merging, and correlation of the data is done by a series of specialized programs in the telemetry functional area of the NDPF.

The data are placed in this file either in original bit configuration or calibrated into engineering units. There are 128 channels in each data frame telemetered. Two channels are subcommutated and can sample different sources throughout the 128 frame commutating cycle. One record computed as 32 frames of a subcommutated sequence as attitude/orbit information is needed at this interval. The total daily input of data to this file is computed as follows:

- Telemetry = 128 channels x 32 frames = 4096 points

7/8 of the 4096 points uncalibrated	3584 bytes
1/8 of the 4096 points calibrated	2048
Eight hardware flags/frame	246
GMT	192
Orbit/attitude	200
Accounting	12
Total	6282 bytes

- One record every 36.80 seconds
- Number of records/day = $\frac{86,400 \text{ sec/day}}{36.80 \text{ sec/record}}$

  = 2348 records/day

- 2348 records/day x 6282 bits/record = 14.7 megabytes/day

This large volume of daily input data and the specialized use of the file data dictates that this file is generated and maintained in the telemetry processing stream of the NDPF rather than handling and processing the data via the information management program.

5

Data Collection System

The DCS file provides a history of all ground sensor data collected and transmitted via the data collection platforms. Data is transmitted from the platforms to the observatory and then relayed to tracking stations which send the data to the OCC.

At the OCC the data are decommutated, time-tagged, and written in digital form on magnetic tape. These data are then input to the NDPF. Here the DCS data are processed and changed into engineering units for input to the information management program for updating the DCS history file. During this processing the DCS platform file is used to obtain data such as geographic coordinates for the DCS file.

The file is organized by collection platform and its sensors. When more definitive information becomes available about the specific sensors and users responsibilities for sensor data, the file may well be organized by user agency and the sensors collecting data for that agency. Data content of these records is as follows:

- Platform number
- Platform location
- Sensor
- Agency - investigator
- Acquisition site
- Orbit - revolution
- Date
- Time (GMT)
- Parameters 1 through 8

Approximately 4100 DCS messages are received each day. Each message contains eight sensor readouts which total approximately 40 bytes of data. Therefore each sensor is sampled approximately 20 times a day for Case A (4100 messages/day ÷ 200 platforms = 20.5 messages/day/platform). The total daily input to the DCS file is 164,000 bytes. Although each platform record is less than 80 bytes of data, it will grow at a rate of 810 bytes a day (20.5 messages/day/platform x 40 bytes/messages).

This file is maintained on tape due to the volume of input data. Standard user outputs provide users information only on the ground sensors for which they are responsible or on which they wish to receive information.

Some of the features and capabilities of this file in conjunction with the information management program are:

- Automatic updating
- Batch updating
- Retrievals using Boolean logic
- Standardized outputs
- Special formatted reports
- Output media - tape, cards, listings

Production Control Status File

This file contains the current status and summary information on all jobs and work requests in the NDPF. The file is structured so that each process controlled in the NDPF comprises a subrecord tied to a fixed record identifier. Each process that is monitored by production control submits a transaction to the production control file either on punched card or from an interactive terminal. Format of these transactions is standardized as much as possible to simplify the processing and maintenance of the file by the information management program.

The production control file is used daily with batch updates from each transaction recorded on cards and throughout the day with transactions from terminals. The file is used to provide periodic summary reports and is capable of providing the current status on any job or work request.

The production control file consists of a standardized set of records and subrecords for each process monitored in this functional area. The data content of these records is as follows:

- Identification record

  Job/work request number
  Date entered and recorded
  Orbit number
  Type identification

- Function subrecord

  Function identification
  Date done

- Storage subrecord

  Storage location
  Date stored

- Quality subrecord

  Quality code
  Function
  Date

Record sizes vary but average 60 characters/record. Assuming an average retention rate of 15 days from initial entry of a job or work request and a retention rate of 30 days after completion of these requests, the production control status file will contain between 10,000 to 20,000 records during normal operation. This requires an on-line storage capability for approximately 1.2×10^6 characters.

Some of the features and capabilities of this file in conjunction with the information management program are:

- Automatic updating
- Display and terminal update
- Update multiple records
- Batch updating
- Retrievals using Boolean logic
- Audit of data prior to update
- Formatted reports for various levels of detail and summarization
- Special reports when required.

Library Index File

The library index file provides a record of and the location of all physical items stored in the active and archive portions of the library.

Items stored in the library are the final products of a process and, as necessary, the original input data. Based on an analysis of data that should be saved, the length of time it should be maintained and the form it should be stored, the NDPF library is structured into an active and an archive library. The archive storage area may be physically separate from the NDPF but a record of data stored there is maintained in the library index.

The file is updated daily with new acquisitions and is used in servicing requests for data in the library. For ease of updating and retrieval from a terminal, the file is stored on a direct access device.

The items to be stored in the library comprise data files; processed imagery in roll film, cut film, and print form; catalogs; and digitized imagery. A record is made of each item. The data content of the records is as follows:

- Accession number
- Data content
- Storage form
- Storage location
- Date of data
- Date placed in library
- Suspense date
- Placed in archives
- Office prime responsibility
- Source of data
- Archive subrecord
- Storage form
- Storage location
- Data content.

Each record has about 80 characters. The file is very small initially and gradually increases in size. The rate of growth will depend on the number of separate items stored and the retention period for these items.

Some of the features and capabilities of this file in conjunction with the information management program are:

- Display and update at a terminal
- Batch updating
- Standard formatted outputs of holding
- Special listings of holdings.

Time History File

This file is a history of previously verified and corrected GMT. The time history file is used to keep the time continuity of the PCM telemetry throughout the lifetime of each ERTS. This file provides the only source of data to correctly time annotate the playback data when received separately from the real-time data.

The time history file is used in the preprocessing phase of the PCM data reduction stream. Data for input to this file is generated by the time verification and correction section of the preprocessor.

The file consists of several directory records and many time line entries. The directory record is a quick index to the location of the time reference desired. The time line entries give the time characteristics of a segment of continuous data.

The daily input to this file is one entry of 42 bytes to the directory. The number of time line entries is variable but an average of two to three is expected. Each time line entry consists of 72 bytes.

Data Collection Platform File

The DCP file contains data on each platform location and the calibration data on each sensor. This file is used in the DCS processing stream to change the DCS data into engineering units.

The structure and size of this file cannot be estimated at this time because the sensors have to be calibrated and their values have not been determined.

3.4.2.2 Operation

The information management capability is comprised of a number of individual programs, which in addition to performing the storage and retrieval functional processes also control internal input/output, executive control, and utility programs which sequence and organize the functional program jobs and data flow. The information management program (IMP) is composed of the following major programs:

- File creation
- File revision

- File maintenance
- Retrieval and sort
- Output generator
- Remote terminal processing.

The file creation, file revision, and file maintenance components are primarily concerned with the creation, reorganization and maintenance of the system files. The retrieval and sort component is the primary information retrieval tool while the output generator component provides for formal report production. Finally, the remote terminal processing component provides remote file interrogation, entry and output capabilities through remote (or local) input/output terminals.

The file creation component or module embodies the facility to create a file structure through the processing of a file format specification developed and input by the information management program user. It also embodies elements which are necessary to the compilation of file processing specifications and the creation of file processing instructions which are retained in an applications library and used as required in subsequent operations (e.g., file maintenance). Those elements which are especially required to generate the data file and data file index are also considered in the file creation component, although the program logic of the file maintenance component is utilized and shared in these operations.

The input processing module performs operations on input data transactions prior to their entry into the data file. It must edit the input data in accordance with an input processing specification prepared by the IMP user whose form and means of specification is a matter of individual information management program design. The input processing module must also provide for the sorting of the input data transactions either prior to their editing or in a follow-on operation.

The file maintenance module embodies the logical elements necessary to generate a file plus those added elements required to process an input data file and data file index. The file processing specifications also reflect and include those additional elements which are necessary to direct

the addition, modification and deletion of data file/index values, subsets and records as indicated by the contents of the incoming data transactions. The ability to audit the input file contents during file maintenance is also required to enable a logical determination of file update actions and to produce an audit trial of data input and file values as directed by the file processing specification.

The file revision module provides the capability to readily revise the format in which file data is stored. This is accomplished by a comparison of the file format direction describing the file in its current format to the file format specification describing the file in its revised format. The file revision module generates instructions to cause copying of selected data elements from the current file into the new format. In this process, the addition, deletion and limited relocation of fields as well as changes to their size and name is allowed.

The retrieval and sort module uses a simple English-like, condition/action language which is flexible in notation. By specifying the retrieval conditions, the information management program user causes specific records/data to be retrieved from the data file. Comparison operations are provided to include "equal to," "less than" and "greater than." A negative operator "not" is provided to optionally precede any of all of the comparison operators. Boolean connectors are used and at least two levels of nested parentheses are included. A geographic retrieval operator permits an irregular area search. This includes area-to-area, area-to-line, point-to-point, and point-to-area search capabilities. Area searches are performed against both convex and concave shaped polygons. Provision is made to describe the search areas in terms of three to eight or more point locations. The capability to "call in" previously compiled subroutines and tables for the purpose of data value conversions, etc., is provided. The sort specification permits sorting on fields in the master segment of the data file record and fields in the periodic segments which appear in the retrieval data. Exhaustive diagnostics on the retrieval and sort specification are performed to provide directions for error correction to the information management program user. Once error free, the retrieval specification is made available in compiled form for inclusion in

an applications library from which it may be called in standard production activities.

The output generation module includes the capability to format complex reports. In addition to this it allows logical conditioning in its computational and output actions to produce summarizations, totals and subtotals.

In formulating the output, the output generation module provides for the insertion of headings and page numbers in printed output and permits control over pagination and line spacing. The output generation module also produces tape and card output in a format compatible to these media. The output generation module performs logical and arithmetic operations that include the use of literally defined work areas and values. The capability to "call-in" previously work areas compiled subroutines and tables for data conversion, etc., is provided. Input data for the module is forwarded from the retrieval and sort process or directly from the master data file. The data report specifications that define the output report use a language that allows structuring by nonprogrammer personnel. The output generation module performs exhaustive diagnostics on the data report specifications to provide direction for correction of errors in the format specification. Once error free, the report specification is made available in compiled form for inclusion in an applications library from which it may be called in standard production activities.

The remote processing module provides an easy-to-use means of querying and updating an information management program data file. Provision for permitting the user to enter data is made without exposing a file or its contents to inadvertent modification or destruction. Requests for data from a file are performed in a manner facilitated by the processing terminal. The query language used is comparable in capability and expression with the query language employed in the retrieval and sort module.

3.4.3 User Interface

A user liaison office is required within the system configuration because of the continual need for NDPF to interface with all users. The main purpose of this office is to provide the management vehicle for

efficient and precise exchange of data, to be able to answer user questions, to assure quick response to user queries, to make sure user abstracts are quickly entered into the system, and to assure delivery of all requested and bulk image products on time.

The user has access to the NDPF through this office and a browse library.

3.4.3.1 Request and Dissemination Procedures

The system essentially has two standard operational modes. One mode involves the standard bulk production requirements created by a typical 18-day period. Indexes are created, limited abstracting is performed by the NDPF, the index/abstract catalog is produced, and all standard imagery (film and montage catalogs) is prepared and disseminated to the users. Request and dissemination procedures are straightforward for these products since everything entering the system is processed and reformatted for delivery from the system to the users.

The second mode of operation involves the handling of special processing requests. This procedure is more complex because a number of production control activities must be performed to allow the request to be processed expeditiously and the results to be distributed on time and to the quality expected. Three types of requests will be common: a request for precision imagery, a request for information from the data files, or a combination of both.

A request for precision imagery first involves a search of the files to determine whether or not the precision processing has been accomplished previously for another user. If it had there would be no need to repeat the processing but instead the system would initiate a work order to reproduce the archival copy. If the processing had not been accomplished a work order would be initiated to schedule the job. Dissemination of the product is completed only after quality control and appropriate indexing and archiving had been accomplished.

A request for information from the data files takes three forms: a generalized set of gross search parameters which are translated into machine language; a specific query already coded or keypunched and ready

for entry into the system; and a browse mode where a user has access to the data base via the use of a hard-copy library containing index listings, montage catalogs, maps, etc.

3.4.3.2 Types of User Interface

Two types of user interface are maintained by the NDPF: one where the system configuration allows processing common to a number of users, with the users performing further processing unique to their needs at their own centers, and a second interface where the user is completely reliant upon the NDPF for its end products and analyses. In each case the system produces standard and special products, but the nature of these products may be different. Each type of interface is discussed in more detail below.

To be of maximum service to all users the NDPF system is designed to provide products in a variety of user formats, but also accepts user abstracts and maintains a central repository for all users' information. This enables the small user to benefit from the analyses of all the other users, whether they be small or large. The NASA data base thus becomes the vehicle for data exchange, and the generalized information handling system allows NDPF to accept, process, and produce data in a variety of forms and formats, as required.

There are a number of different variables which might affect the extent of a user's in-house capability. Assume, for example, the situation where the user has a minimum data processing facility for handling index/abstract data, but no precise image processing. It is reasonable in this case that the NDPF does special image processing by request for that customer, and it is logistically easier and operationally less expensive to distribute the index/abstract file in either magnetic tape or punched card form. The user then has a direct machine-readable input to his system for processing in any manner desired. On the other hand, a user with a large image processing capability can request limited coverage digital image tapes. The standard products to a user having an in-house capability include RBV/MSS coverage indexes, abstract catalogs in both machine readable and hard-copy montage catalogs, and hard-copy

imagery. Special products include hard-copy imagery and machine-readable information in the usual case, and machine-readable imagery (digitized tapes) and high precision imagery in the case where the user has a large image-processing capability of his own.

The user interface is interactive in the sense that NDPF provides a data exchange and inquiry service to all users, whether the users have a data processing capability or not. This requires hardware appropriate to the evolving requirements of the user and software that allows a common exchange of data in two directions: for maintenance of all users' abstracts, and for inquiry and index searching in response to requests. The information management programs allow all users a common input mode to the data files, a common English-like language for retrieving data from all files in the system, and a flexible report generation and formatting capability consistent with all user's product needs.

Two types of user information inquiries are serviced -- searches of previously abstracted and stored data, retrievable by location, dates, attributes, frame numbers, etc.; and, standing requests for new data as new mission inputs are received. Request and dissemination procedures apply to both information queries from the central data files and also to the various standard and special products of the system (the montage catalogs, special imagery, film, etc.). Control of this process is provided by a production control system with well defined procedures.

3.4.4 Management Control Procedures

In addition to the procedures associated with the two major modes of operation (bulk and precision) in the NDPF there are a number of day-to-day management responsibilities which transcend both modes. Generally these responsibilities can be grouped into the following categories:

- Data services photo lab support
- User liaison and job control procedures
- Production control procedures
- Library and archive management
- Program testing and debugging.

Since all imagery (except that delivered to users in digital form) must be duplicated for distribution (negatives, positive transparencies, and prints, color prints, and montage prints) the data services laboratory has the responsibility to support both the bulk and request operational modes. The duplication procedures and techniques used affect both the quality and quantity of the product as well as the operational efficiency. Some of the photo lab functions requiring procedures are as follows:

- Contact printing
- Enlargement printing
- Integrated color printing
- Montage printing
- Print drying
- Photograph mounting
- Enlarging
- Trimming prints
- Mixing chemicals
- Ordering and stocking chemicals
- Ordering and stocking reproduction materials
- Maintaining quality control between the master negatives and subsequent photo generations
- Maintaining repeatability of product quality
- Control reproduction process by monitoring temperatures, solutions, flow rates, pH measurements, etc.
- Maintenance of equipment.

3.4.5 Production Control

The production control function is responsible for the overall coordination of the NDPF operation. Control is maintained and operation is monitored on a continuing near real-time basis.

To perform this broad responsibility, the production control system is in continuous contact with all other functions in the NDPF. The

communication is bidirectional, with general and detail schedules and summaries originating from production control and detail progress or status information returning to the production control system from all other functions.

The production control function includes:

1) Job Control

- Identification - the development of standards identifying jobs and their required input and output.
- Definition - defining the sequential functions to be performed for successful completion of a job.
- Scheduling - the relating of the sequential function, jobs and resources in a chronological relation.
- Monitoring - relating actual schedules to predicted schedules.

2) Process Control

- Process Identification - the development of standards and controls on the operations to be performed.
- Resource Monitoring - the continuous checking of resource utilization and performance.
- Performance Monitoring - the continuous auditing of the overall NDPF operations.
- Quality Control - the review of the input and output of the operational functions.

3) Data Control

- Status/progress Data - the maintenance of current status of jobs, resources, and inventory at a detail level.
- Summary Data - condensation of the detail data for more effective presentation to management.
- Historical Data - data maintained in less accessible form for other than current or active jobs.

4) Management

- Workload Analysis - presentations of data or the current and projected activity by resource or function.

- Performance Analysis - a review of the scheduling and quality performance of a resource or function.
- Plans - organized input that forms the basis for production control direction to the operating functions.
- Schedules - the day to day direction to function or resources.

Inputs to the production control function are in the forms of job progress, status information, schedules, and planning information delivered to the computer or keypunch support area in the form of transactions.

These transactions are audited and then used to update current status files stored in the computer. The files are then used to generate detailed and summary reports for use by all affected functional operations.

The reports and transactions generated on the computer are in turn distributed to the responsible operational function to control the operation.

3.5 LIBRARY FUNCTIONS

The NDPF library operates as a service and support function. It is a self-contained unit which responds to the needs of functions in the bulk and request modes which require information stored in the library. All magnetic tapes (video and data) are maintained by the library, as are the miscellaneous hard-copy reports which the system generates, the various reference materials used in the system, and the photographic film.

There are two sections to the library, an active library and an archival storage area. The active library maintains tapes and data which are current and which may be requested at any time for request processing. The archives represent the storage facility needed for all data and tapes which are outdated but still usable. They must be retained but the number of requests are infrequent and therefore do not justify retention in the active files. The archives could conceivably be maintained in another area of the building or even in another facility.

An important factor is the retention period for data in both the active and archived portion of the library. The periods selected are based on a combination of the study of NDPF requirements (e.g., data volume

and utilization) and experience with similar government systems (e.g., NASA-GSFC for telemetry data, Defense Intelligence Agency for images).

In the case of image data, film has a useful life approaching 200 years. All government agencies handling film (including the Departments of Defense, Interior, Agriculture, and Commerce), have a policy of never destroying the original film material or capability to reproduce it. Since it may be necessary to perform precision image processing several years after acquisition, high-density digital storage of images is required. Since recopying of these tapes is necessary every 5 to 10 years a test tape will be generated and run periodically to determine when tapes have to be recopied.

The library also stores all final products of the system, updated data file histories, supplementary reference data as received from either users or other outside agencies, and raw tapes prior to processing. The library is also responsible for providing up-to-date reference materials to the proper functional areas such as all current maps which must be ordered from other agencies to support the photo interpreter at the screening stations.

The data types stored by the library are summarized in Tables 3-5 through 3-7. The library is responsible for storing in retrievable and reproducible form all the data passing through the NDPF. There are basically three categories of data: 1) imagery in raw and processed form, 2) information in digital form, and 3) hard-copy archival data, both imagery and data. These are discussed below.

Imagery is received by the system primarily in video magnetic tape form, or in some instances it is received over wideband communication links for real-time processing. However, since all imagery received is processed in some manner the system provides storage locations for the video (both analog and digital) in the archival files, both prior to image processing and subsequent to processing. The imagery is then processed further — in the bulk mode where it is transformed into film and film products such as the montage catalog; and, in either the special request or precision mode where it is digitized, processed, and transformed into

Table 3-5. Imagery Storage Requirements

Data		Active Library								Archive Library					Comments
Category	Item	Original Form	Media	Volume	Period	Update Cycle	Keep	Data Disposition	Remarks	Form	Media*	Recopy Cycle	Keep	Remarks	
Original Input Imagery	RBV	Analog	VT	4 tapes	Daily	None	3 mo	Archives							
	MSS	Analog	VT	4 tapes	Daily	None	3 mo	Archives							
Bulk-mode Digital Imagery	RBV	Digital	HD	Case A: 1 tape Case B: 3 tapes	Daily	None	1 yr	Archives	100% bulk	Digital	HD	Based on test type	Indef		Case A: 315 frames/day
	MSS	Digital	HD	Case A: 1 tape Case B- 3 tapes	Daily	None	1 yr	Archives	100% bulk	Digital	HD	Based on test tape	Indef.		Case B: 1315 frames/day
Request-mode Digital Imagery	RBV Precision	Digital	MT	A-9 frames	Daily	None	1 yr	Destroy	5% bulk						Case B, ERTS B: 25 frames/day
	MSS Precision	Digital	MT	A-13 frames	Daily	None	1 yr	Destroy	5% bulk						Case B, ERTS B: 41 frames/day
	RBV Digital	Digital	MT	A-2 frames	Daily	None	1 yr	Destroy	1% bulk						Case B, ERTS B: 5 frames/day
	MSS Digital	Digital	MT	A-13 frames	Daily	None	1 yr	Destroy	5% bulk						Case B, ERTS B: 41 frames/day

*LEGEND
VT - Video Tape
MT - Magnetic tape
HD - High density magnetic tape
Archives - GSFC

NOTE: Frame and set rates for table
ERTS A, Case A 8-hr day, 5-day week
ERTS B, Case B: 24-hour day, 7-day week

Table 3-6. Information Storage Requirements

Data		Active Library								Archive Library					Comments
Category	Item	Original Form	Media	Volume	Period	Update Cycle	Keep	Data Disposition	Remarks	Form	Media*	Recopy Cycle	Keep	Remarks	
Original Input Data	Spacecraft telemetry	Analog	MT	20 tapes	Daily	None	6 mo	Archives							Data in master digital data file
	Ephemeris	Digital	MT	1 tape	Daily	None	6 mo	Archives							Data in master digital data and attitude history files
	DCS	Analog	MT	6 tapes	Daily	None	6 mo	Archives							Data in DCS file
Data Files	Index/ abstract	Digital	Disc	31,500 bytes	Daily	Daily	5 yr	Archives	Case A	Digital	HD	As needed	15-30 yr	**	ERTS B, Case B, Vol= 115,500 bytes/day
	DCS	Digital	MT	164,000 bytes	Daily	Daily	5 yr	Archives	Case A	Digital	HD	As needed	15-30 yr	**	ERTS B, Case B, Vol= 820,000 bytes/day
	Master digital data	Digital	MT	14.7 megabytes	Daily	Daily	1 yr	Archives		Digital	HD	As needed	15-30 yr	**	
	Attitude history	Digital	MT	13,200 bytes	Daily	Daily	5 yr	Archives		Digital	MT	As needed	15-30 yr	**	** Recopy cycle of archive tapes will be based on results of test tape checks
	Time history	Digital	Disc	200 bytes	Daily	Daily	5 yr	Archives		Digital	MT	As needed	15-30 yr	**	
	DCP	Digital	Disc	Small	As needed	As needed	Indef.	Purge	As req'd						
	Ground reference	Digital	Disc	40,000 bytes	Weekly	Weekly	Indef.	Purge	As req'd						
	Map reference	Digital	Disc	Small	As needed	Monthly	Indef.	Purge	As req'd						
	Production control	Digital	Disc	6,000 bytes	Daily	Daily	Indef.	Purge	As req'd						
	Library index	Digital	Disc	8,000 bytes	Daily	Daily	Indef.	Purge	As req'd						

*LEGEND:
VT - Video tape
MT - Magnetic tape
HD - High density magnetic tape
Archives - GSFC

NOTE: Frame and set rates for table
ERTS A, Case A: 8-hour day, 5-day week
ERTS B, Case B 24-hour day, 7-day week

Table 3-7. Hard-Copy Storage Requirements

Data		Active Library									Archive Library					Comments
				Volume												
Category	Data Item	Original Item	Media	ERTS A Case A	ERTS B Case B	Period	Update Cycle	Keep	Data Disposition	Remarks	Form	Media	Recopy Cycle	Keep	Remarks	
Hard-Copy Imagery																
Bulk	RBV	BW image	Film	189	495	Daily	None	1 mo	See Comments	Frames/day						Destroy after bulk corrected
	MSS	BW image	Film	252	825	Daily	None	1 mo	See Comments	Frames/day						Destroy after bulk corrected
Bulk Corrected	RBV	BW image	Film	189	495	Daily	None	5 yr	Archives	Frames/day	BW image	Film	200 yr	Indef		Master is second generation positive
	MSS	BW image	Film	252	825	Daily	None	5 yr	Archives	Frames/day	BW image	Film	200 yr	Indef		Master is second generation positive
	RBV composite	Color image	Film	13	33	Daily	None	5 yr	Archives	Set/day	Color image	Film	100 yr	Indef		Master is second generation positive
	MSS composite	Color image	Film	13	33	Daily	None	5 yr	Archives	Set/day	Color image	Film	100 yr	Indef		Master is second generation positive
Analog Precision	RBV	BW image	Film	9	25	Daily	None	5 yr	Archives	Frames/day	BW image	Film	200 yr	Indef		Master is second generation positive
	MSS	BW image	Film	12	41	Daily	None	5 yr	Archives	Frames/day	BW image	Film	200 yr	Indef		Master is second generation positive
	RBV composite	Color image	Film	3	8	Daily	None	5 yr	Archives	Set/day	Color image	Film	200 yr	Indef		Master is second generation positive
	MSS composite	Color image	Film	3	8	Daily	None	5 yr	Archives	Set/day	Color image	Film	100 yr	Indef		Master is second generation positive
Digital Precision	RBV	BW image	Film	9	25	Daily	None	5 yr	Archives	Frames/day	BW image	Film	200 yr	Indef		Master is first generation positive
	MSS	BW image	Film	12	41	Daily	None	5 yr	Archives	Frames/day	BW image	Film	200 yr	Indef		Master is first generation positive
	RBV composite	Color image	Film	3	8	Daily	None	5 yr	Archives	Set/day	Color image	Film	100 yr	Indef		Master is third generation negative
	MSS composite	Color image	Film	3	8	Daily	None	5 yr	Archives	Set/day	Color image	Film	100 yr	Indef		Master is third generation negative
	Montage catalog	Image Mosaic	Film	2 sheets		18 days	None	5 yr	Archives		Image	Film	200 yr	Indef		Bind into one volume yearly
Hard-Copy Documents	Abstract catalog	Alpha-numerics	Paper	Variable		18 days	None	5 yr	Destroy							
	Maps	Paper	Film	300		Monthly	Monthly	Indef	Purge	As Req'd						Maps will be on film

NOTE: Frame and set rates for table

ERTS A, Case A: 8-hour day, 5-day week
ERTS B, Case B: 24-hour day, 7-day week

either film or digital tapes. The outputs of the image processing steps are sent to the users and copies are stored. The copies may be in a number of forms, from a 9-1/2-inch roll or cut film to 35 or 70 mm film, or in large volume high density storage media.

Information in digital form is also retained by the system. Information is received in both digital form (orbital parameters) and in PCM form (spacecraft telemetry and DCS), and data is created within the system in digital form (all the information management files, master digital tape, etc.). Much of this digital data is stored for subsequent retrieval, either on magnetic tape or on-line on disks or other direct-access devices.

The third category of data to be stored is the hard-copy listings, catalogs, maps, charts, overlays, etc. Some of these data must be retained for future reference (e.g., maps to assist in the internal processes such as image screening, external support such as montage catalogs for user browsing, or special data retrievals which should be retained). The three categories (imagery, digital information, and hard-copy) make up the requirements of the archival files.

3.5.1 Imagery Storage

Imagery is stored in four basic forms:

- Raw video (RBV) and PCM (MSS) tapes
- Digital tape (1600 bpi)
- Processed film
- Archival storage tape.

The raw video and PCM tapes are retained temporarily because they represent the bulk data in its original form. Video and PCM tapes are thus retained in the active file during the period when most of the image processing is performed.

Digital imagery is a required product of 10 percent of the incoming MSS data and 1 percent of the RBV data. This type of digital imagery represents little or no corrections and is essentially a digital representation of the original images. It is not necessarily advantageous to retain copies of these data since the original tapes are available as backup.

Digital tape is also the result of precision processing and is stored in the archives, for a short period of time. This is primarily because of the high cost of producing a precision image, and because the image is in digital form at the completion of the precision process. If the precision image is required in film form it will undergo a conversion by the film recorder, but is still retained on tape in its precise digital form.

Processed film, in the form of master negatives, positive transparencies and prints, false color composites, and montage sheets, of each product are retained by the library.

Because of the large volume of imagery being produced by the system, and the need for precision processing of the stored images, there is a need for large volume archival storage.

A tradeoff study was conducted to determine the best match between the ERTS data load and available archiving techniques capable of implementation during 1972. This study included an analysis of the ERTS input information to determine the best form of archiving, analog or digital, optical or magnetic. In addition, the study included a survey of the current techniques and equipment applicable to the problem. Factors considered in the analysis included media costs, permanence, reliability, availability, storage volume requirements, accessibility, and equipment requirements and costs. This study is reported in detail in Volume 17.

The results of the study indicate that ultra-high-density digital archiving is the most suitable solution to the ERTS archiving problem. There are a number of reasons for this conclusion. The first consideration is the form of archiving, digital or optical analog. The optical imagery provides an excellent long-term storage medium, however, where subsequent digitization and precision processing is required, it is not possible to obtain an undegraded readback of the data, even with the best of state-of-the-art scanning equipment. The decision is therefore to archive all ERTS data in digital form. The various forms of high-density digital archiving were then considered. Both optical and magnetic techniques and equipment are available to solve this problem, however, the lower risk of ultra-high-density magnetic storage as opposed to laser

optical recording and holographic storage outweigh the assured permanence of the optical media. The use of ultra high density magnetic tape, in 14- to 16-inch reels, 1-inch wide was thus selected. The unit of access although not optimum for retrieval is preferable for insertion of the data into the archive. Since the amount of data which will actually be retrieved is low compared to that inserted this appears to be the best compromise.

The ultra-high-density magnetic storage approach selected provides data permanence nearly equal to optical storage if proper storage environment and strict handling procedures are employed. Since the data is non-saturation recorded on a magnetically neutral base (not magnetized) and the coding method maintains short wavelengths, there is no physical reason for data loss if proper storage conditions are met.

Ultra-high-density recording systems are available from several manufacturers. The pertinent characteristics are listed below:

Surface density: 0.5×10^6 bits/in.^{2}

Volume density: 2.28×10^8 bits/cu. in.

Unit of access: 6.72×10^{10} bits or 106 sets

Reel diameter: 14 to 16 inches

Linear density: 20,000 to 30,000 bits/in.

Tracks/inch: 28 to 32

Cost per bit: 0.15 microcents

Cost per image set: 1.00 dollar

Read/record rate: 30 Mbits/sec

3.5.2 Information Storage

In addition to the storage requirements for imagery discussed above, there is a need to store a large volume of information in digital form. This data can be broadly classified as being either telemetry/spacecraft derived or generated within the system as information management files:

Telemetry/Spacecraft Data	Management Files
Master digital data	Index/abstract
Spacecraft performance	Library index
DCS	Production control status
Orbital ephemeris	
Time history	

A discussion of each category of digital data follows, the telemetry/spacecraft data being treated as a group, and the management information files being discussed separately.

3.5.2.1 Telemetry and Spacecraft Data

This data is processed as a function of the telemetry and image data processing unit, and it is used to initiate the index/abstract and annotation files and to produce the master digital tape, the spacecraft performance data, the attitude history, and the DCS data tapes, all of which must be stored by the system.

During processing the data is maintained on magnetic tapes. Archival storage of working data (e.g., index/abstract) is on direct access media, while less frequently requested data (e.g., digital telemetry, ephemeris, DCS, annotation, time reference, master digital, etc.) is retained permanently on magnetic tape.

3.5.2.2 Index/Abstract Data

As the system accumulates coverage over several years the index/abstract files will become larger, growing as a function of the indexable ground coverage and the user abstract inputs. After a firm data base is established there will be limited growth, with most modifications being changes to the existing files. Each frame or set of coverage is indexed and stored in a direct access storage device so that user requests for information can be fulfilled in as short a period of time as possible. Because of the large volume of index data, and because of the response needs, it is impractical to store the data on a serial-search medium such as magnetic tape.

There are essentially three types of data to be stored in such a file: 1) the index for each frame of coverage, 2) annotation data, and 3) abstracted data from the users for each frame of coverage. The index data elements are inserted by the NDPF. The abstract data elements are provided primarily by the 10 different users. The volumes here are more difficult to estimate because it is not known to what extent the user will be furnishing inputs. Annotation data for film labeling is retained in the file for future changes brought about by either more precise geographic positioning or as the result of precision processing. This portion of the file will grow according to the Case A and B rates, plus additional records for precision image annotations.

It should be noted that even though seven frames per set will be exposed (three RBV and four MSS) only one set is indexed. There is no need to provide three duplicate records for each of the RBV frames in one set (four for MSS). Within each record there are data fields allowing reference to the spectral band exposures within each set.

3.5.2.3 Library Index

It is necessary in the ERTS system to not only index the image frames according to where they are in the world (their ground coverage) as discussed in the previous section, but it is also necessary to keep a physical inventory of the master negatives, any positive transparencies or prints retained, and any precision processed imagery. That is, in order to find the pertinent film to satisfy a user's request, there must be a two-level search. The first level identifies that film which is available; the second tells him where in the library that piece of material is located.

The index/abstract file could conceivably retain this information, but for quicker access and more flexible file maintenance, it is more practical to build and maintain a separate library index. Whereas the index/abstract file is organized by frames within a mission, the archival index is organized by frames and missions within a roll of film, and that roll of film further identified by room, shelf, or bin location.

3.5.2.4 Production Control Status

As discussed in previous sections the production control function is necessary for providing a number of services, such as insuring availability of supplies, insuring delivery of correct raw materials, processing and managing user requests, scheduling resources, reporting management control information, etc. The data management system will perform the majority of the functions of production control and will require data files, including:

- o Data received and not processed
- o Available resource descriptions and limitations
- o Supplies inventories
- o Catalogs of available data
- o Open user requests
- o Transaction histories.

3.5.3 Hard-Copy Archives

The hard-copy archives are necessary for the storage of reference materials. The data consists of montage catalogs, retrieval listings, plots, maps, hard bound index/abstract catalogs, etc. The archives consist of materials generated by NDPF and materials of reference used in the browse files.

3.6 FACILITY PLAN

The NDPF will occupy the major portion of the computer floor area of the second floor of Building 23 (approximately 12,500 square feet excluding areas shared by the OCC). TRW's plan for a modular-designed facility makes maximum use of the existing space. TRW has planned the location of the rooms and work areas to optimize both data and production flow.

The electronic equipment area will be separated from the photo processing area by a physical and air-conditioning barrier.* This

*The barrier also separates the photo processing area from the OCC.

modification is required to prevent exposure of the GDHS electronic equipment to chemicals and possible damage of equipment located in lower floors by chemical leaks.

3.6.1 Electronic Areas

Those areas not requiring special treatment due to photo-chemicals are listed below:

- Electronic Data Processing (Room W-208). NDPF computer activities are conducted here. The TRW planned equipment layout together with the existing facility layout (with minor modification), is able to support high volume data processing equipment effectively. The electronic data processing equipment is laid out for the convenience of operations personnel and for easy maintenance. (The electronic equipment maintenance room joins the electronic data processing.) Corridor partitions contain glass sections so that visitors have an opportunity to see equipment operations on their way to the browse room or while on a conducted tour.

- Tape Library (Room C-2106). The tape library is next to the electronic data processing area, ensuring a smooth, uninterrupted data flow. Tape retention and retrieval activities are centered here. The library also joins the staging area, increasing the efficiency of scheduling activities. Staging personnel are able to physically control library data and prevent unauthorized entry.

  TRW has selected tape library cabinets that allow for system growth. These can be realigned for high density tape reel retention, increasing reel capacity one hundred percent over standard cabinets in the same floor space.

- Tape Staging (Room W-204). The location of the tape staging area promotes efficient program scheduling and planning activities. A work counter on the west side of the room is used by programmers to submit their work without interfering with the tape activities. A door from the staging area into the browse area reduces outside traffic and redundant activities.

- Electronic Equipment Maintenance and Electronic Spares/Storage Equipment (Room W-226). The NDPF shares the maintenance and stores areas with the OCC, reducing space requirements and redundant efforts. As the maintenance area adjoins the electronic data processing room, electronic equipment service is facilitated.

The above functions occupy 5116 square feet excluding the electronic maintenance and electronic spares/stores area which are shared with the OCC.

Total space requirements for the major non-photographic elements are:

Area	Square Feet
Electronic data processing	3600
Tape library and staging	1516
Electronic equipment maintenance (shared with OCC)	750
Electronic spares/stores (shared with OCC)	332

Only minor facilities modifications are needed. TRW's plan uses most of the existing area improvements without adversely affecting equipment layout and operating procedures. The area selected requires realignment of existing partitions and doors, the computer floor system, air conditioning system, and lighting.

Power panels, leads, and equipment ground systems require major realignments, but will not affect the main building system because of the minor overall loading modification requirements described above. Early occupancy will not interfere with the completion of the GDHS facility.

3.6.2 Photo Processing Areas

The photo-processing areas are totally contained within the chemical section of the computer floor area. The plan is to provide isolation from other floors, the OCC, and electronic areas. The method of isolation is by means of a floor seal and fume barrier.

The floor seal is placed on the subfloor under the computer floor. The seal provides a fume barrier between the photo-processing areas and the electronic equipment air plenums under the computer floor. The construction of the seal allows for a drainage point and sump pump.

The fume barrier is basically the floor seal below the computer floor, the wall separating the photo-area from the electronic equipment area, and the air conditioning air balance. The air balance provides a negative air pressure in the photo-areas and a positive air pressure in all surrounding areas. This air balance forces the air into rather than out of the chemical fume producing areas. Since much of the photo processing equipment requires exhausting directly out of the building the negative pressure can be obtained with minor modifications.

The layout of equipment and rooms allows the support of the high production photo processing yet provides specialized work areas. The production flows of raw stock from the staging is designed not to interfere with production activities.

The photo and image processing areas utilize the east half of the computer floor area and occupy 7435 square feet of work space. The area is basically utilized in the following way:

Area	Square Feet
Image processing	4596
Film recording room	425
Staging and film makeup	1190
Production control/mail-out	450
Film library	300
Process control	187
Maintenance room	287

The TRW modification plan has made maximum use of the existing facilities. Because of the requirements for photo processing and hazards control of the processing chemicals, special provisions must be made as follows:

- Chemical resistant floor seal
- Fume barriers
- Chemical waste system

- Water supply systems
- Fume exhaust system
- Darkroom lighting system
- Modify ceiling for dark rooms
- Modify lighting systems
- Major wall relocations
- Vibration control system for critical equipment
- Air conditioning system balance.

The TRW modification plan includes provisions for containing all water and drain systems within the floor seal area. All modifications allow the facility to be returned to its existing condition with minimum modification. The chemical waste system makes special provision for anti-pollution and chemical control.

3.7 HARDWARE SUMMARY

This section lists and describes the hardware items associated with image and photographic processing. Other hardware in the NDPF is part of the computing/display system and is discussed elsewhere. The items to be described in this section are the following:

- RBV tape reproducer
- MSS tape reproducer
- RBV bulk process control unit
- MSS bulk process control unit
- High density tape recorder/reproducer
- High density tape control unit
- Tape-to-film control unit
- Laser beam recorder
- Precision photo restitutor
- Geodetic control measurement station
- RBV tape recorder
- Photoprocessing equipment

3.7.1 RBV Tape Reproducer

The RBV tape reproducer is used to play back the RBV bulk video and housekeeping telemetry data on the RBV tapes received from the ground stations. It has been assumed that the GFE ground station recorder will be the RCA TR-70-CVR-3 recording video data at 7.5 in./sec, although the specific recorder has not been selected by NASA at present.

The RCA tape reproducer (RCA No. TR-5-CVR-LO-25/4-3) consists essentially of a tape playback unit with a playback speed reduction of 6.25:1(1.2 in./sec tape speed). Playback speed can be varied ±5 percent from nominal by an external reference signal from the RBV bulk process control unit. Data input rate to the control unit is controlled by this means in order to prevent overflow or underflow of data. Playback at the 6.25:1 reduced rate provides the equivalent of a digitally converted pixel output of 800 kilopixels/sec. Signal-to-noise ratio degradation contributed by the reduced speed playback is less than 1 db compared to playback at the original speed (on the order of 40 db).

The reproducer accepts 2-inch analog magnetic tape and has capabilities for read forward on longitudinal track and high-speed rewind as well as status and warning signal indications.

Format of the input magnetic tape will be FM analog baseband video, 4125 scans noninterlaced at 800 microseconds per scan, 90 percent duty factor, 3.5 MHz bandwidth per spectral image. Output format is serial readout of the three spectral band images in 9.5 seconds, with repetition every 25 seconds during real-time operation. During spacecraft recorder playback modes the repetition interval may decrease to every 15 seconds. Raw telemetry data is recorded on a single longitudinal track on each video tape.

3.7.2 RBV Bulk Process Control Unit

This unit controls the motion of the synchronous RBV reproducer to accept video image data and PCM telemetry data, to digitize and buffer a portion of the image data, to introduce identifying header, annotation, and photometric correction data supplied by the computer, to control the

output of all but the telemetry data in a standard, compact format suitable for input to a synchronous high density tape recorder, and to control the motion of the high-density tape recorder. The RBV control unit also provides a high-speed channel interface with the computer for exchanging general process control commands and status codes, inputting calibration image data from RBV tape to the computer for photometric correction computation, transferring specific telemetry data to the computer, and outputting the header, annotation, and photometric correction data from the computer to the control unit. The control unit interfaces directly with the RBV tape reproducer, the computer, and an archival high-density tape drive. The four functional modules comprising the RBV bulk process control unit are shown in Figure 3-14.

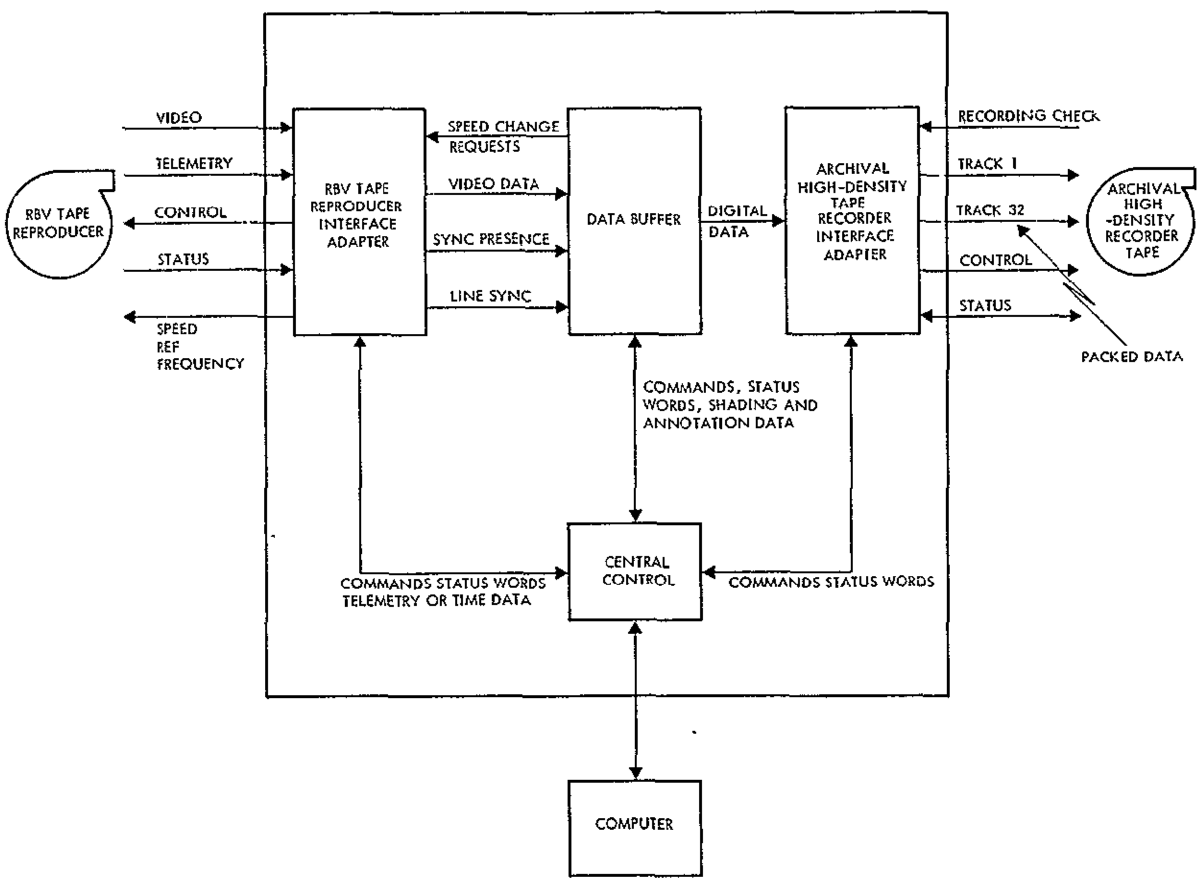


Figure 3-14
RBV BULK PROCESS CONTROL UNIT functional block diagram

The central control module provides a common path for commands, requests, status codes, and data between the computer and the modules of the bulk process control unit in a manner similar to that of a standard peripheral control device, directing and monitoring several other devices and passing information between them and the computer. The module provides the ready-receive and buffering logic necessary for high-speed command/request communication between a computer and peripheral devices. Information is transferred in a standard format such as 8-bit bytes with a ninth bit for parity check. The maximum rate of transfer can be on the order of 800,000 bytes/sec (800 kbits/sec) in the case of transferring calibration images to the computer.

The central control module monitors request lines from the RBV tape reproducer interface adapter, the data buffer, and the archival high density tape recorder interface adapter modules for any request for communication with the computer, establishing a path between the requesting module and the computer. Module requests are serviced on a priority basis with the archival high density tape recorder interface adapter given the highest priority, followed by the RBV tape reproducer interface adapter and then the data buffer. Routing of commands or data from the computer to the module designated by the computer is through the central control module.

The central control module also provides the capability for primarily offline operation in the transfer of RBV image data and associated data to archival tape. Initial RBV tape setup must be directed through computer-generated commands routed to the RBV tape reproducer interface adapter followed by an initiating command from the computer to the central control module. The module executes a hardwired routine, generating coded commands and tagging them so that they may be routed to the appropriate module to cause the tape drives to start and synchronize and to effect the reformatting and transfer of data from both the RBV tape and the computer to the archival tape. Progress is monitored through discrete digital status signals from the various modules and through control counters noting the number of images and the current image lines and picture elements being transferred to the archival tape. A basic

clock is provided to be employed throughout the bulk process control unit as well as all timing signals necessary to execute the hardwired process control and monitoring routine.

The control logic within the RBV tape reproducer interface adapter module provides the capability of accepting coded commands from the central control module and decoding the commands to generate discrete digital motion commands to the RBV tape reproducer unit. The module is also capable of generating a sequence of discrete motion commands according to a hardwired routine for initially setting up the tape and confirming the tape identity.

The RBV tape recorder interface adapter module monitors discrete digital status signals from the RBV reproducer and upon request from the central control module encodes one of these signals or internal operational status words for ultimate transfer to the computer. Fault indications from the reproducer are encoded and a request for service is initiated to the central control module.

A reference signal is provided to the reproducer for capstan drive speed control. The reference is step variable ±5 percent around the nominal frequency. Any reference signal variation causes an equal variation in the reproducer playback speed from the nominal. This provides the ability to control the data input rate to the data buffer so that overflow or underflow of data is avoided. The reference signal is maintained at the nominal frequency or stepped to either limit based on discrete digital signals provided by the data buffer module.

The RBV tape reproducer interface adapter monitors the RBV video channel output to determine image identification and location. The RBV video channel format, shown in Figure 3-15, places horizontal sync frequency preceding every image set of three spectral bands and the subsequent vertical sync frequency preceding each image; the time of exposure of each image is coded in PCM format and interlaced with the vertical sync frequency. Calibration images containing shading information are identified by a unique code in place of the time code. Images are thus identified by time code and position relative to the horizontal sync.

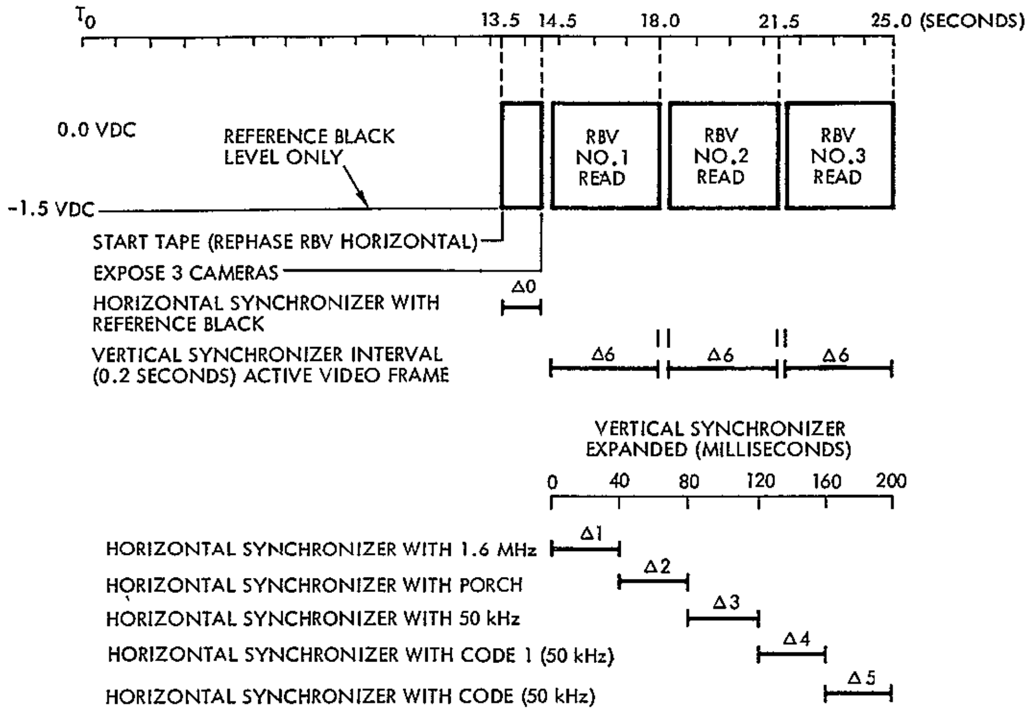


Figure 3-15
GENERAL RBV TAPE FORMAT

A discrete digital output signal is generated whenever the horizontal sync frequency is present and a second discrete output is generated when the vertical sync is present. The time code or calibration image identifier interlaced with vertical sync is stripped out and compared against time code data supplied by the computer to establish initial tape positioning. The discrete signal indicating the presence of vertical sync is passed also to the data buffer to aid in initiating data digitization at the appropriate time. Each scan of RBV image data is preceded by a sync pulse as shown in Figure 3-16. The interface adapter module strips these pulses out for use in monitoring progress at the central control module and for a data output rate indication to the data buffer module.

The module provides the capability for identifying and stripping specific requested PCM data from the telemetry channel, buffering the data, and providing it in parallel format for input to the computer through the central control module. Raw PCM conditioning, message sync code recognition, and word counting are performed to select the desired data from the message.

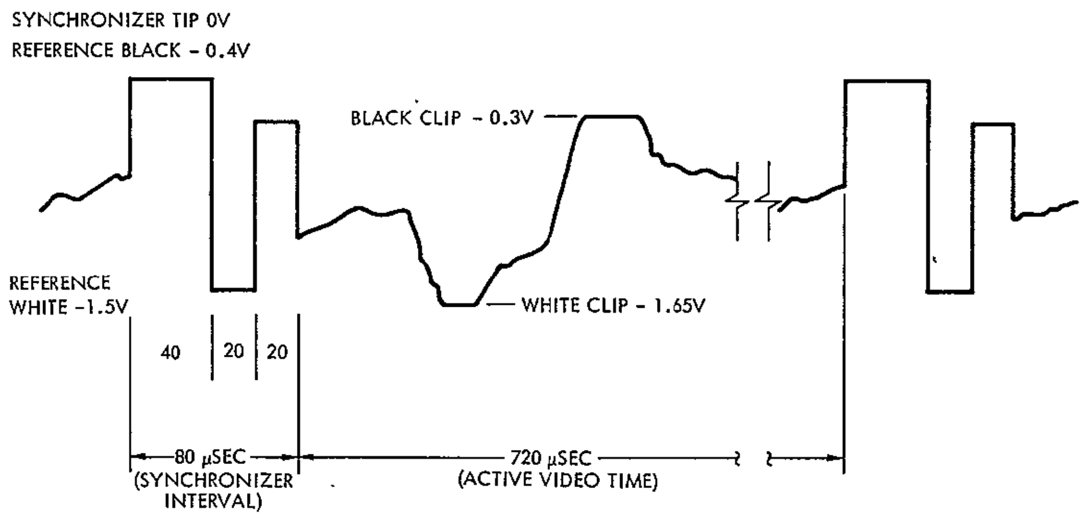


Figure 3-16
RBV VIDEO SCAN LINE FORMAT

The RBV data buffer provides a capability for conversion from the video data format output by the RBV tape reproducer to discrete digital data which can be more successfully archived over a long period of time and can be input to the computer for processing and correction. The data buffer accepts video data from the RBV reproducer playing at 6.25:1 reduction from the recording rate and converts the data into 7-bit digital quantities at approximately 800,000 pixels/sec (800 kilopixels/sec). The vertical sync indicator and pulses indicating RBV tape reproducer output data rate, provided by the RBV tape interface module, provide sufficient information to control the generation of conversion commands in order to sample each scan line the desired 4096 times.

Data storage is provided for a sufficient amount of digitized image data to be supplied continuously to the high-density tape even with differences in input and output data rates. Simple step control is provided to vary the input data rate by varying the speed of the RBV reproducer; however, the high inertia characteristics of the RBV tape reproducer permit only speed changes requiring several scan times. An image buffer provides the required dynamic storage to ensure that data will not overflow and that data will always be available for outputting. An additional 22 kbytes of storage provides the capability for accepting digital header,

annotation, and photometric correction data to be merged on the archival tape with the image data.

The data buffer provides the capability to select from storage either the image data or the other data to be merged, to assemble it into a "packed" word, (i.e., not necessarily allocating a standard byte for each element (or character in the case of header and annotation data), and to output the packed data to the archival high-density tape recorder at a precisely controlled rate of 200,000 words per second using timing supplied by the central control module. The archival tape field allocations and format are shown in Figure 3-17 with leading header followed by annotation information, photometric correction data, image data, and a trailing identifier similar to the leading header. Field identifying codes and data synchronizing preamble codes are generated as the data is output.

Data can also be provided to the central control module when required to input to the computer the calibration images recorded on the RBV tape. The calibration image data is transferred to the computer one pixel at a time, formatted as a standard byte. The data is transferred at approximately the RBV tape input data rate, 800 kilopixels/sec.

Monitoring of the image buffer's filling and emptying process and generation of the necessary speed change requests to the RBV tape reproducer interface adapter module are provided by the data buffer module. The data buffer also accepts coded commands and configures the format to provide image data to the archival tape or calibration data to the central control module. Requests for new header, annotation, and photometric correction data are initiated at appropriate times as the image transfer progresses.

The archival high density tape recorder interface adapter module provides the capability for accepting coded commands from the central control module and decoding them to generate discrete digital motion commands to the archival tape recorder. The module monitors discrete digital status signals from the tape recorder and upon request from the central control module encodes one of these or an internal operational

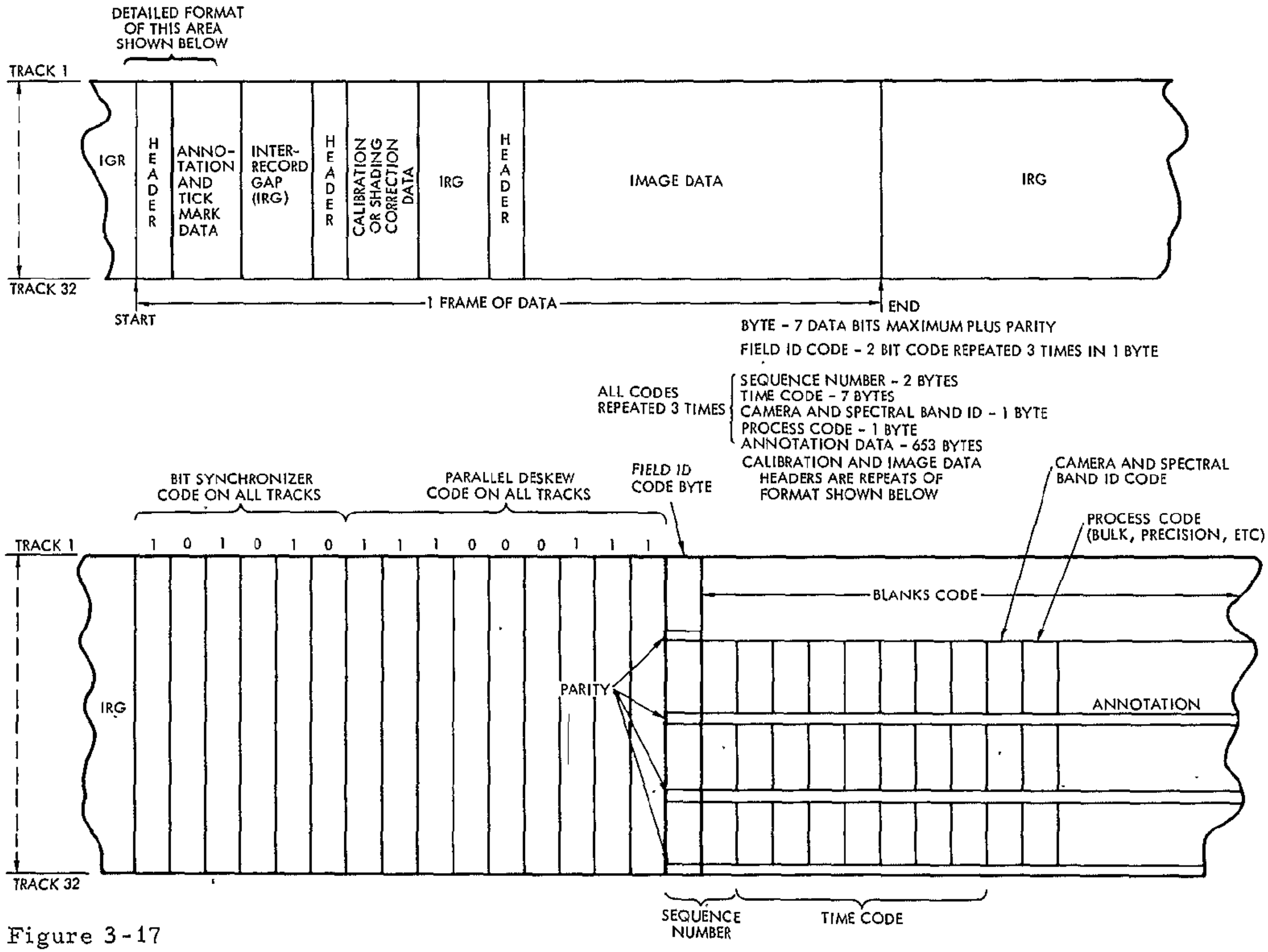


Figure 3-17

ARCHIVAL TAPE FORMAT

status word for ultimate transfer to the computer. Fault indications from the recorder are encoded and a request for service is initiated by this module to the central control module.

A fixed reference frequency is provided by the interface adapter module to be recorded with the data for playback speed control. The recorder controls tape speed internally for the record operation.

3.7.3 MSS Tape Reproducer

The MSS tape reproducer reproduces the MSS bulk video and housekeeping telemetry on the MSS tapes received from the ground stations. It has been assumed that the GFE ground station recorder, not at present defined by NASA, will be the Ampex FR 1928; this is basically the Ampex FR 1900 with a 28-channel head stack and speeds of 60 and 15 in./sec. Recording will be at 60 in./sec.

The MSS tape reproducer is also the Ampex 1928 with a 28-channel head stack, but has reproduce speeds of 120 and 60 in./sec. Playback will be at 120 inches per second in order to provide the equivalent of 800 kilopixels/sec. Playback speed can be varied at least ±5 percent from the nominal by an external reference signal from the MSS bulk process control unit; this provides for control of data input rate to avoid overflow or underflow of data.

The unit accepts 1-inch high density digital magnetic tape. Tape format is continuous scans of 4096 digital pixels per 100 nautical mile scan, 2600 scans per 100 nautical mile square picture. Picture elements are quantized to six digital bits. Four spectral bands of video are recorded in parallel, with six scans per spectral band at a 67-percent duty factor. The fifth spectral band for ERTS-B is recorded on a single additional channel in multiplex mode. Raw telemetry data is recorded on a single longitudinal track.

The reproducer interfaces directly with the MSS bulk process control unit.

3.7.4 MSS Bulk Process Control Unit

The MSS bulk process control unit provides the capability to accept raw data read from MSS image tapes and to supply framed image data

and identifying annotation and calibration data for storage on a high-density tape for archival storage in a format useful to bulk image reproduction or computer precision processing. This unit controls the motion of the synchronous MSS tape reproducer, searches the MSS tape, and establishes the desired initial positions for framing continuous scan data into separate images, selects image data and calibration data associated with one spectral band from among four recorded in parallel, and dynamically buffers and reformats the data from that band. It also introduces identifying header and annotation data supplied by the computer, outputs the data to an archival high-density tape recorder in a standard, compact format identical to the format generated in the RBV bulk process; and controls the motion of the synchronous high-density tape recorder. A standard channel interface with the computer permits the exchange of general process control commands and status codes, the outputting of search information to the control unit to direct the setup of the MSS tape for each image set, as well as the outputting of header and annotation information from the computer. The MSS bulk process control unit interfaces directly with the MSS tape reproducer, the computer, and an archival high-density tape drive. Four modules comprise this bulk line control unit, as shown in Figure 3-18.

The central control module provides a common communication interface between all four modules and the computer, passing requests and status codes generated by the various modules to the computer and commands, status codes, and data from the computer to the designated modules. The ready-receive and buffering functions provided permit standard command/request communication between the computer and the peripheral bulk process control unit modules. Information is transferred in a standard format such as 8-bit bytes and a ninth bit for parity at a maximum rate of 500,000 bytes/sec (500 kbits/sec). This module also provides the capability for offline control of the process of transferring image, calibration, header, and annotation data to the archival tape through a hardwired routine. Initialization of the line is directed through computer control followed by a process initiating command from the computer. The routine provides the capability to generate coded commands

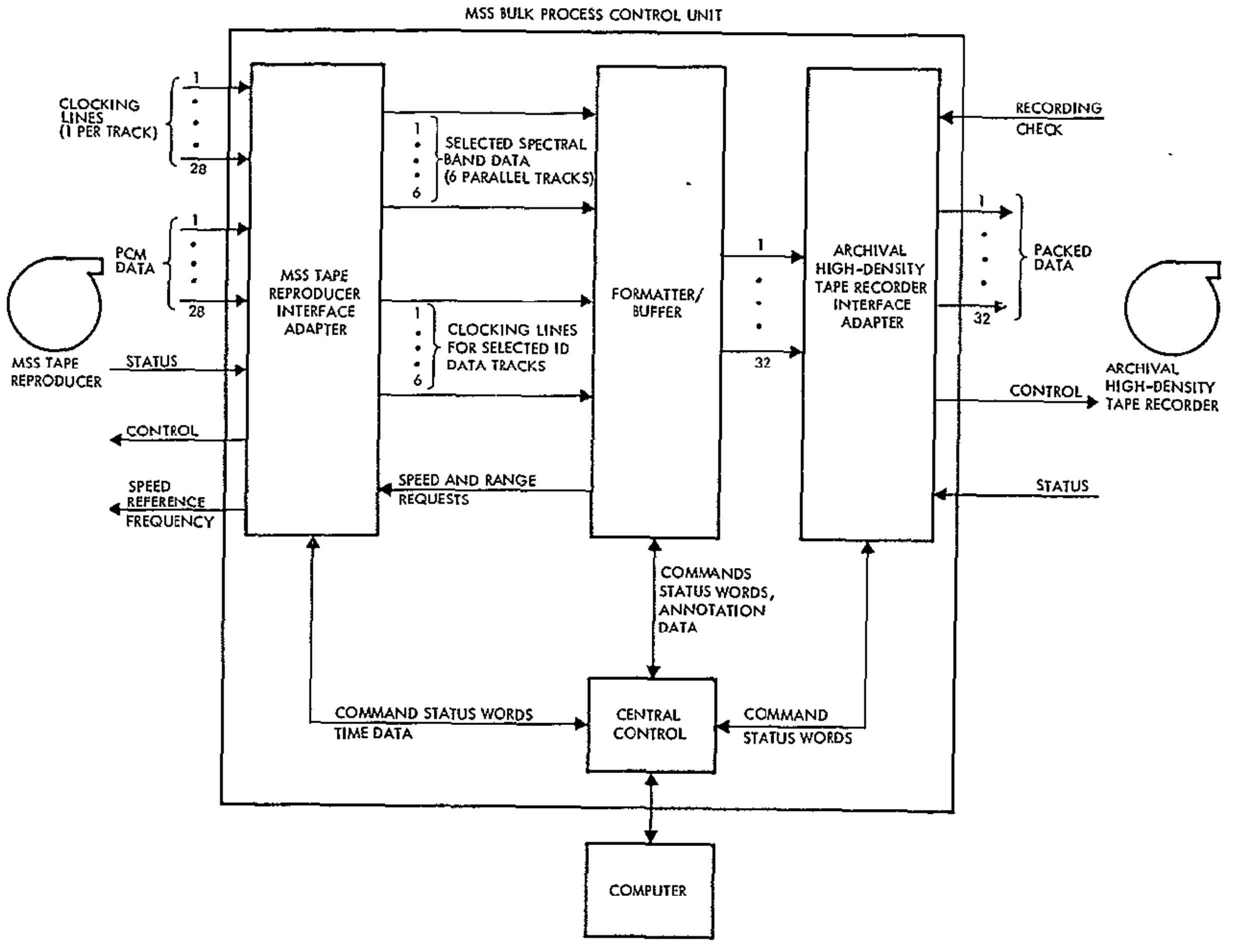


Figure 3-18
MSS BULK PROCESS CONTROL UNIT functional block diagram

and route them to the appropriate modules to cause the tape drives to start and synchronize; to effect the reformatting of the image data from the desired spectral band along with the header, annotation, and calibration data; and to transfer the data to the archival high-density tape. The process is monitored in the central control module through discrete digital signals provided by the various modules. Any fault indication is is encoded at the specific module exhibiting the failure and transferred through the central control module to the computer for further direction. The central control module provides the basic clock and timing signals necessary to bulk process control unit operation.

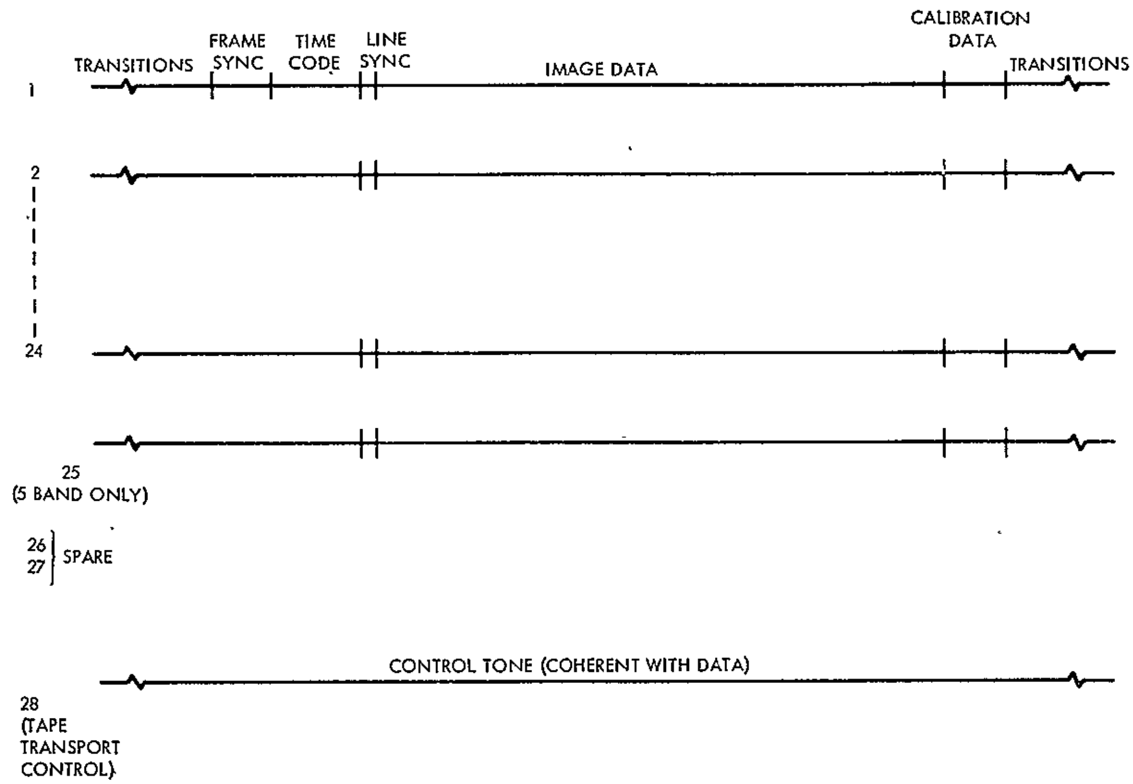


Figure 3-19
MSS TAPE FORMAT

The MSS tape reproducer interface adapter module controls and monitors the operation of the MSS tape reproducer, exchanges command and status information with the central control module, and controls the flow of data from the tape reproducer to the formatter/buffer module. It is capable of accepting coded commands from the central control module and interpreting them to generate discrete digital motion commands to the tape reproducer. The MSS interface adapter generates motion commands autonomously in order to perform a search of the PCM data on the MSS tape and locate the initial scan line of an image. A time code is designated by the computer through the central control module followed by a command to initiate search. The time codes present on track 1 of the 28-track tape, as shown in Figure 3-19, are identified by the interface adapter as the tape is read backward or forward. The codes are compared to within a one scan tolerance (≈67ms) against the time code supplied by the computer. Having found the desired scan line, the tape

interface adapter automatically positions the tape to provide sufficient time on startup for the reproducer to attain fully-synchronized operation prior to reading that data. The tape setup routine also provides the ability to relocate the starting position on the tape after each image of a set; however, the location of each new image set must be established from a new time code supplied by the computer.

The MSS tape reproducer interface adapter provides the capability to condition the raw PCM data readout from all 24 data tracks and to select for output only the six tracks associated with the current spectral band image to be archived. The appropriate six clocking tracks to be used for individual track bit sync, derived in the tape reproducer, are provided along with the six data tracks to the formatter/buffer to accomplish effective data buffering, reformatting, and output to the archival tape.

Discrete digital status signals provided by the reproducer are monitored and encoded upon request from the central control module to be input to the computer. Fault indications from the reproducer are encoded and a request for service is initiated by the interface adapter to the central control module.

The MSS tape reproducer interface adapter also provides a variable frequency reference signal to vary the speed of the tape reproducer. The reference signal can be maintained at nominal or stepped to a 5 percent higher frequency at the request of the formatter/buffer in order to control the output data rate from the MSS reproducer. The 5 percent increase in frequency increases the data rate from a nominal 195 to 205 kbits/sec per track.

The formatter/buffer module interfaces with all other modules in the MSS bulk process. It accepts image and calibration data read out through the MSS tape reproducer interface adapter, accepts commands and header and annotation data from the central control module, supplies speed change requests to the MSS tape reproducer interface adapter, outputs status information to the central control module, and supplies reformatted data to the archival high-density tape through the archival high-density tape recorder interface adapter.

The six lines of PCM data representing six different scan lines exhibit bit skew between adjacent tracks greater than one bit; therefore, each data track is accompanied by its own clocking track. The formatter/buffer maintains separate bit synchronization for each track at a data rate of approximately 1.2 Mbits/sec, recognizing the image sync code in each line and maintaining bit count thereafter in order to strip out the 6-bit image or calibration samples for storage. Each line is allocated an area of storage for its 4096 samples; an additional area is provided for buffering of header and annotation data supplied by the computer and the calibration data stripped from the PCM data lines. The formatter/buffer provides the capability to accept the six scan lines simultaneously while outputting scan lines serially. The image data portion of the buffer is composed of two sections, each providing sufficient storage capacity for six lines of data. As data from one buffer is output to archival tape, the other is being filled. This 50 kilopixels of storage is also sufficient to output data continuously as differences in input and output data rates cause dynamic buildup or underflow and the input data rate is adjusted.

The formatter/buffer provides the capability to select from each area of storage the appropriate data to be supplied to archival tape. The data is merged on tape in the same format as for the RBV bulk line as shown in Figure 3-15. All data is assembled into "packed" words and output to the archival high density tape recorder at a precisely controlled rate of 200,000 words per second using timing from the central control module. The field identifying codes and data synchronizing preamble codes are generated by the formatter/buffer. The filling and emptying of the buffer is monitored and necessary discrete digital speed change requests to the MSS tape recorder interface adapter are generated in the data buffer. The formatter/buffer is also capable of accepting coded commands and header or annotation data from the central control module. Status and fault conditions are encoded and a service request initiated to the central control module.

The archival high-density tape recorder interface adapter provides the identical capabilities attributed to that module in the RBV bulk process control unit description. The module controls and monitors the operation

of the archival high density tape recorder, exchanging commands and status information with the central control module and interfacing the recorder with the formatter/buffer. Coded motion commands from the central control module are interpreted and discrete digital commands generated to control tape recorder motion. Discrete digital status conditions provided by the recorder are encoded upon request and supplied to the central control module. Fault indications from the recorder are encoded and a service request initiated to the central control module. A fixed reference frequency is provided to the tape recorder to be recorded with the data for playback speed control.

3.7.5 High Density Tape Drive

High density record/reproducer units interface with various equipment to provide the means for archiving all bulk data in digital form, for reading the data to generate film imagery, or for input and output of image data to the computer. Regardless of their specific functions within the NDPF, all the high-density tape drives provide identical performance capabilities.

The high-density tape drive units record or reproduce digital data at several selectable rates which can be externally varied about the nominal rate. Data rates of 100, 200, 400, 800, and 1600 kbits/sec per track on 32 parallel tracks can be accommodated with bit error rates not exceeding 1 part in 1×10^6. The data rate can be varied ±10 percent through an external reference signal variation. The units are capable of forward reading and writing. A read-after-write capability provides the ability to check the data recording process. Equalization of data at all rates is provided for all read and write operations. The high-density tape units internally generate and output individual clocking signals for each data track to provide bit sync information.

The high-density tape units provide manual operational ready and stop controls, but are otherwise remotely controlled through discrete digital signals. The units provide operational or fault status indications as discrete digital signals to the controlling unit.

3.7.6 High-Density Tape Control Unit

This unit interfaces an archival high-density tape reproducer or recorder to the computer, generates control commands to the tape unit, and monitors tape recorder operation. Image data and associated data stored on archival tapes are input to the computer through the control unit; conversely, image data and associated data from the computer are output to high-density tape through this unit. The capability to operate in either configuration is provided within one unit; the desired configuration is switch selectable.

For both configurations the control unit provides a communication path with the computer over a standard high-speed channel interface. The ready-receive and buffering provided can establish and sustain channel operation at a data rate of 800, 000 image pixels per second. A unique address code is assigned to each control unit. This code, output by the computer, alerts the unit to respond and thus establish communication with the computer to enable the control unit to accept data or coded commands from the computer. The control unit initiates service requests to establish communication and input data or status words to the computer. All information is transferred in a standard computer format, such as 8-bit bytes plus a ninth bit for parity.

The central control unit accepts the coded computer commands and decodes them to generate discrete digital motion commands to the tape unit. The unit is also capable of autonomously generating tape motion commands based on a hardwired routine. To initially position the prerecorded tape for forward readout, an image identifier is supplied by the computer and followed by a command to initiate the search. The control unit is capable of generating commands to cause forward or backward reading of the tape and comparison of identifier codes to determine the desired starting point. The tape is then automatically positioned to ensure proper speed synchronizing prior to data readout. The control unit provides discrete digital motion commands to a recording unit only at the request of the computer.

The control unit encodes discrete digital status signals provided by the tape units or internal operational status either at the request of the computer or as an interrupt to the computer.

The control unit accepts 31 skewed tracks of data at 200 kbits/sec per track from the high density tape reproducer and reformats the data for input to the computer. The unit utilizes 31 individually derived clocking signals provided by the tape unit to aid in synchronizing and deskewing the data. The control unit provides sync code recognition for each track and sufficient buffering to align data skewed as much as 25 bits. The three identifier tracks are not to be input to the computer; the 28 bits of parallel data resulting after alignment are separated into 7-bit samples, reformatted into standard bytes, and input to the computer at 800 kbits/sec.

The control unit accepts individual bytes of data from the computer at 800 kbits/sec and reformats the data for input to the high-density tape recorder. Four bytes containing a total of 28 bits of real information (7 bits of information per byte) are assembled into a word and transmitted to the tape unit at 200,000 words per second. The three tracks of identifying code are generated in the control unit and input concurrently with the 28-bit words. The control unit utilizes the deskew capability previously mentioned, reading all data after it is written to provide a quality check of the recording operation.

3.7.7 Tape-to-Film Control Unit

The tape-to-film control unit accepts data read from RBV or MSS high-density bulk archival tapes or high-density precision processed image tapes and supplies the data to a laser beam image recorder to produce annotated imagery on film. This unit provides:

- Motion control of the synchronous high-density tape reproducers
- Search capability to establish the initial high-density tape position prior to image reproduction
- Ability to distinguish between RBV or MSS, and bulk or precision processed data according to the header

information read from the tape and to cause the line to adapt as required

- Tick marks and a sensitometric gray scale to be merged with image data
- Output of the merged image data to the laser beam recorder at the rate demanded by the laser beam recorder
- Decoding and output of the annotation data to a block annotation device at the LBR
- General motion control of the synchronous laser beam recorder

All process control and monitoring functions are provided by the control unit; no computer interface is required. The tape-to-film control unit interfaces with a high-density tape reproducer and the laser beam recorder. The four modules comprising this control unit are shown in Figure 3-20.

The central control module interfaces with all other modules to operate the line with no computer control. Hardwired routines within the module initiate the line prior to image reproduction, initiate the process monitor progress and status, and stop operation through the exchange of coded command and status words. The central control module monitors the header data read into the data buffer in order to determine the appropriate operational procedure for producing an image. Bulk RBV data is accompanied by photometric correction data which must be applied as a gain factor to the laser beam recorder as the image is produced. Bulk MSS data is accompanied by six sets of eight gray-level samples for calibration; the six gray scales for the six MSS sensors in a given band are to be reproduced on the imagery along with the normal sensitometric gray scale.

Precision processed data requires no further calibration. The laser beam recorder spot size and film speed are adjusted to change from RBV to MSS imagery in order to maintain equal scale reproductions. The central control module configures the line prior to initiating the actual image reproduction for bulk tapes by noting the first header information.

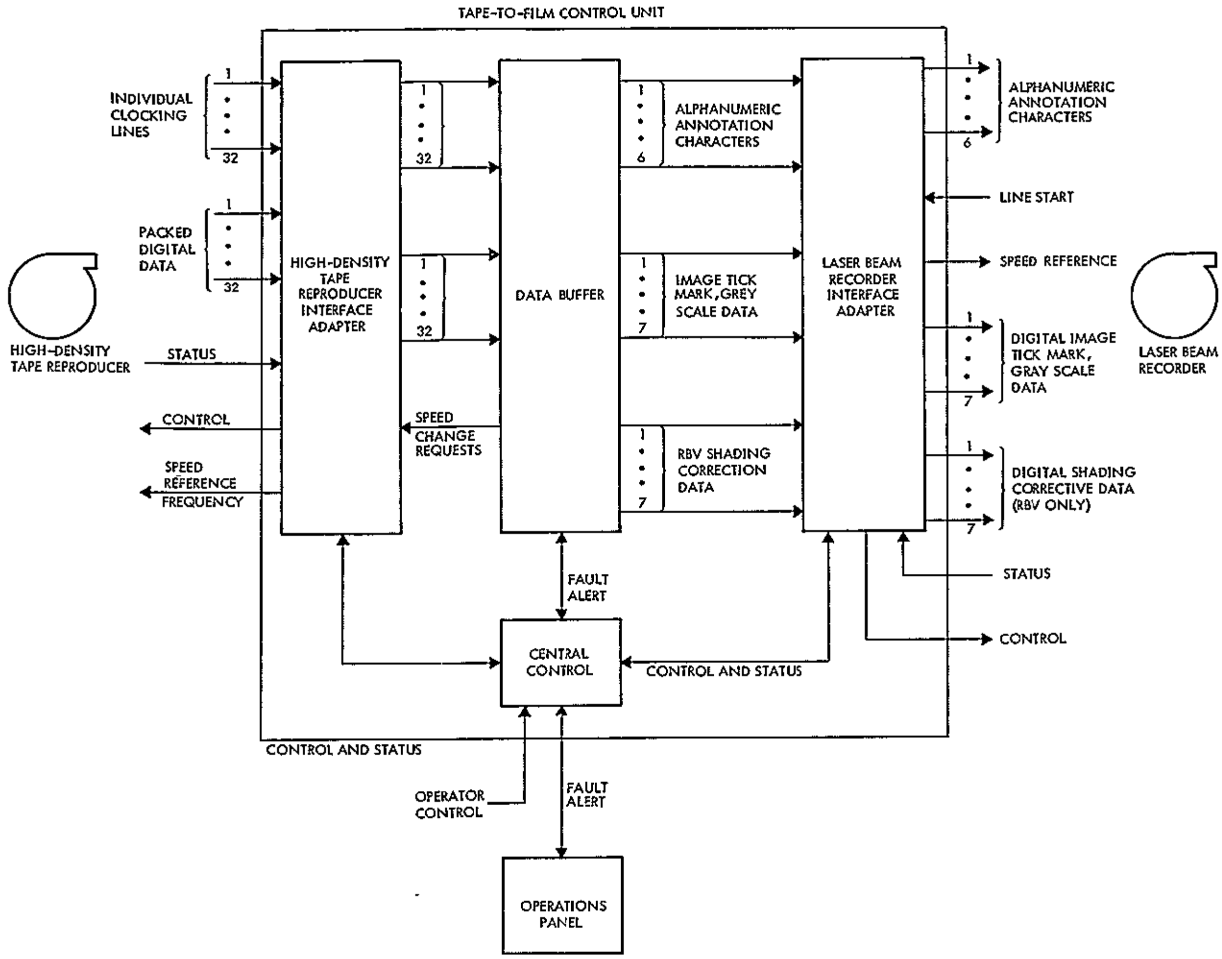


Figure 3-20
TAPE-TO-FILM CONTROL UNIT functional block diagram

Precision processed tapes contain both RBV and MSS imagery, but not intermixed; therefore, the line is configured and image reproduction initiated based on precision processed imagery of one type. When a header appears identifying the other type of image, the central module stops operation to adapt the line to this imagery, causes the input tape to be repositioned approximately, and restarts operation. Coded commands are generated and routed to the module desired. The modules respond with coded status words at the request of the central control, or they are capable of initiating an interrupt to the routine to alert the central control to a fault or unusual condition. The central control module evaluates the severity of the condition and has the ability to attempt to

resume operation or to activate an alarm to an operator to service a designated unit in the line. Basic timing to be used throughout the control unit is provided by the central control module.

The tape reproducer interface adapter module controls the motion and monitors the operation of a high-density tape reproducer unit, exchanging coded command and status words with the central control module and controlling the flow of data from the tape reproducer to the data buffer module. The interface adapter accepts coded commands from the central control module and decodes them to generate discrete digital motion commands to the tape reproducer. Motion commands can also be generated autonomously in the interface adapter during a tape search routine initiated by command from the central control module. The search routine normally causes the tape to be positioned for forward readout of the first recorded image. In certain cases, however, a specific image, not the first on the tape, is designated as the starting point. The interface adapter searches the tape backward or forward recognizing field identifying codes to find the header data and comparing the information in the header to that provided by the central control module to locate the desired initial image. Having located the image, the interface adapter automatically positions the tape to provide sufficient time on startup for the reproducer to attain fully-synchronized operation prior to reaching the desired image. Discrete digital status signals provided by the reproduce unit are monitored and encoded upon request from central control module for progress monitoring or are encoded and presented on an interrupt basis to indicate a fault condition.

The interface adapter accepts 31 tracks of skewed information from the reproducer and 31 individually derived clocking tracks, deskewing the data so that it can be used effectively in its own search routine and in the formatter buffer. Tracks 1 through 28 contain actual data while tracks 29, 30, 31 contain field identifying and image line start codes. The data will be skewed as much as 20 to 25 bits over the width of the tape. The interface adapter accepts the data at a nominal rate of 400 kbits/sec on each track, aligns the data, and outputs it to the data buffer as 31-bit

words at 400,000 words per second which is equivalent to the 1.6M pixels/sec for the image data portion. The interface adapter also provides a variable frequency speed control signal to adjust the speed of the tape reproducer and consequently adjust the output data rate from the tape reproducer. The reference frequency is maintained at nominal or stepped ±5 percent from nominal at the request of the data buffer to vary the tape reproducer speed and consequently the data rate by the same percentage.

The data buffer module accepts, buffers, and controls the flow of data from the tape reproducer to the laser beam recorder as well as generating internal tick marks and sensitometric gray-scale annotation data. The data buffer recognizes the field identifying and line start codes in the last three positions of the 31-bit deskewed words input from the tape reproducer interface module in order to store the other 28 bits in the proper area. Header information is stored as a means of identifying the imagery currently being reproduced and to provide the central control module with information as to the type of imagery for configuration control. Annotation information storage is provided for 400 alphanumeric characters for block annotation and 32 tick mark locations. Storage for calibration data is provided in the data buffer. RBV photometric correction data requires 21 kbytes of storage for gain factors to dynamically adjust laser beam recorder intensity to compensate for shading affects in the RBV cameras.

The six sets of eight gray-scale-level calibration samples associated with an MSS image are stored to be used for generation of sensor calibrations scales to be placed on the MSS images. Precision processed images require no storage of calibration data. Sufficient storage for image data is provided to ensure a continuous data output to the laser beam recorder while dynamic data buildup or underflow is experienced due to differences in input and output data rates. The amount of data accumulating in the buffer is monitored by the data formatter and the necessary speed change requests are sent to the tape reproducer interface adapter to cause the input data rate to be increased or reduced.

The data buffer utilizes the stored annotation data to generate block annotation characters and tick marks in addition to internally generating a sensitometric gray scale to be placed on film along with the images. The alphanumeric character codes are decoded to drive the appropriate segments of character generating equipment at the laser beam recorder. Using the 32 sets of tick mark locations, data simulating image elements is generated to be input along with image data in order to place well-registered horizontal and vertical tick marks on the edges of the images. The data buffer also generates image-like data sufficient to place a gray scale on the image to indicate laser beam recorder and film characteristics.

The data formatter merges the tick mark, grey scale, and image data as it outputs the data at a rate mutually established by the laser beam recorder and the data formatter. The data formatter provides a very stable speed reference signal to the laser beam recorder to cause it to operate in a stable manner at 400 lines per second. The laser beam recorder sends back a pulsed signal which indicates that the laser is at the beginning of a 9-inch line. The data buffer synchronizes to the line start pulses occuring at 400 pps and divides the 2500 microsecond (time per lines) interval between them into 5060 parts—4096 parts for actual image elements, parts allocated for tick marks and gray scale at the sides, and the remainder left blank to be covered by block annotation. The image, tick mark, and grey scale data is output in 6-bit digital values at a rate commensurate with the need to place 5060 elements in one scan interval of 2500 microseconds which is approximately 2 Mp/s.

As bulk RBV imagery is reproduced, the stored photometric correction data is concurrently output in 6-bit digital samples to provide gain compensation (a multiplicative correction) for shading effects. Each correction is applied over a 32-pixel by 25-line zone. Image reproduction from bulk MSS and precision processed data does not utilize this function.

The data formatter is capable of accepting and interpreting coded commands from the central control module and responding with coded status words. Any fault indication is encoded and an interrupt initiated to the central control module.

The laser beam recorder interface adapter controls and monitors the operation of the laser beam recorder, exchanging commands and status information with the central control module and interfacing the laser beam recorder with the data buffer. Coded motion and configuration commands from the central control module are decoded and discrete digital commands are generated for the laser beam recorder. In addition to the normal operational commands to the laser beam recorder and its associated film transport, commands are generated to change the laser beam recorder spot size and the film transport speed to adapt from RBV to MSS imagery. Discrete digital status condition signals provided by the laser beam recorder are encoded upon request and supplied to the central control module. Fault indications from the laser beam recorder are encoded and an interrupt is initiated.

3.7.8 Laser Beam Recorder Unit

The laser beam recorder produces high-resolution film imagery via a precisely formed laser beam horizontally deflected by a high inertia mechanism and intensity modulated by data supplied from high-density tapes. The laser beam recorder provides an integral roll film transport for vertical movement of the film and a block annotation device for placing alphanumeric annotation on the imagery. The laser beam recorder interfaces with the tape-to-film control unit described in Section 3.7.7.

The laser beam recorder accepts digital 7-bit image samples at 2.02M samples per second and converts the data to a continuous analog video stream which modulates the intensity of the laser beam as it exposes the film. The laser beam recorder provides a very stable line scan rate of 400 lines per second outputting a 250-nanosecond pulse at the beginning of each line to phase the outputting of data samples from the tape-to-film control unit. Each 9-inch line of data is composed of 5060 discrete resolution cells to provide the actual image plus tick marks, and gray scale and an area to be block annotated. The laser beam recorder automatically recalibrates itself after each line.

The laser beam recorder provides a constant spot-width commensurate with the requirement to resolve 5060 elements in a 9-inch line, while

the vertical dimension can be adjusted to compensate for the differences in MSS and RBV image structure. MSS images composed of 2604 scan lines and RBV images composed of 4125 lines are both to be reproduced to the same geometric scale. A vertical image dimension of 7.3 inches must then be covered by either number of lines; therefore, the spot size is increased or decreased upon command from the tape-to-film control unit as the type of imaging being reproduced changes.

The film transport provides movement of the roll film to provide vertical displacement of the laser beam down the image in synchronism with the line scan rate. The film transport moves the film at the rate required to provide a contiguous image of equal geometric scale for either MSS or RBV data. The rate of motion is increased in conjunction with laser spot height increase for MSS imagery (which has the lower number of lines). A rapid film advance feature provides unsynchronized film motion at four times the fastest synchronized advance rate.

External calibration in the form of digital samples values can be input at a maximum of 2.02M samples per second to the laser beam recorder providing multiplicative corrections to the image data. For operation with bulk RBV images, the laser beam recorder accepts digital values representing shading correction factors, converts the digital data to an analog video data stream, and applies the video data to circuitry which adjusts the amplitude of the analog image data and subsequently the laser intensity. Each shading factor is to be applied over a 32-pixel by 25-line zone of the image; therefore the shading corrections occur 128 times per line but the value changes within one pixel as a shading zone interface is crossed.

The laser beam recorder provides the capability to accept and buffer 400 alphanumeric character codes for flashing block annotation data on the imagery. The 6-bit character codes are provided by the tape-to-film control unit in a predetermined order at 1000 characters per second. The codes are stored and decoded to drive appropriate segments of character generation equipment when the tape-to-film control unit commands the flashing of the annotation.

The laser beam recorder accepts discrete digital commands from the tape-to-film control unit and activates the mechanisms and control circuitry necessary to proper operation. The laser beam recorder provides discrete digital status signals to the control unit to indicate several operational conditions or faults.

3.7.9 RBV Tape Recorder

The RBV tape recorder records the RBV video data in real-time as it is received at the NDPF. The signal originates in the NTTF and is routed via a video link to the NDPF via the OCC.

This tape recorder is an RCA TR-70-CVR-3, which is the same recorder as that assumed to be at the ground stations. The video data is recorded at 7.5 in./sec, thus the data available for the reproducer is identical to that received from the ground station except that there will be no spacecraft housekeeping telemetry recorded on the longitudinal track.

A special quick-look mode of RBV images is provided for as follows. Video data in real-time is provided to the NDPF from the NTTF via the OCC. A tape recorder is provided, which is similar to the one used at the ground stations, to record video data at 7.5 in./sec. A few frames of data are recorded early in the real-time pass over NTTF. The tape is then rewound, removed from the tape recorder, mounted on the RBV tape reproducer, and played into the system. The data is accessed to the computer via the RBV bulk process control unit and formatted for output to the digital display generator. The latter device presents the data for display on any console display as selected from either the NDPF or the OCC consoles.

3.7.10 Precision Photographic Restitutor

The precision photographic restitutor is a highly accurate electro-optical device that is capable of printing an output image so that it is in registration with a second or control image, even though there may be high-order relative geometric distortions between the two images. The precision photographic restitutor can be operated so that it may restitute an image in a known or preprogrammed manner.

Corrected images are annotated by a tick mark and fiducial mark generator directly after image exposure. Alphanumeric data is added by exposing the film to a cathode-ray tube station.

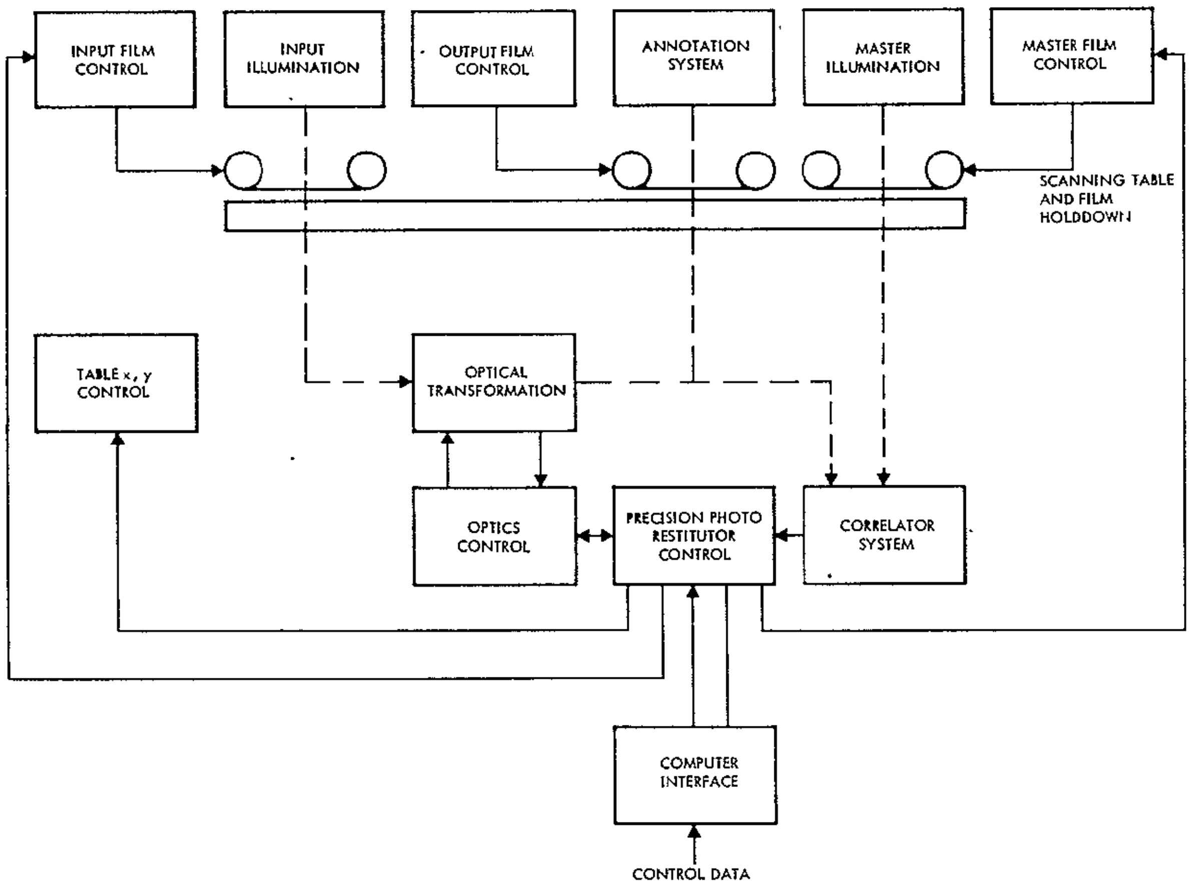


Figure 3-21
PRECISION PHOTO RESTITUTOR functional block diagram

3.7.10.1 Functional Requirements

A functional block diagram of the precision photographic restitutor is shown in Figure 3-21. The input, master, and output unexposed film rolls are mounted on a scanning table which moves in x and y coordinates. As the table scans in the y-direction, a small area of the input image, defined by a slit, is focused on the output film after the image has been transformed by the optical system. The transformed image and the master image are correlated to derive error signals which correct the optical

transformation. The following functional subsystems are part of the precision photographic restitutor system:

- Scanning Table. The three film rolls are mounted on a common scanning table. Film hold-down mechanisms for each film are included.
- Table x, y Control. Precise velocity and position controls for x and y table drives are included.
- Input Film Control. This controls slew rate and input film positioning. A binary code reader for detecting frame identification code is also included.
- Master Film Control. This control is functionally identical to input film control.
- Output Film Control. Slew rate and output film positioning are controlled by this subsystem.
- Input Illumination Subsystem. The output film is exposed through the optical transformation subsystem. Exposure control and color filter selection functions are included.
- Master Illumination Subsystem. The master image is illuminated for the correlation sensor.
- Optical Transformation Subsystem. The following optical transformations are included: Δx, Δy, magnification, and rotation.
- Optics Control. The Δx, Δy, magnification, and rotation parameters are controlled in velocity and position.
- Correlator Subsystem. An analog image correlation system using imaging tubes to scan the input and master images make up this subsystem. Zero- and first-order distortions are measured to develop error signals which are applied to the deflection of the image tubes. A correlation quality signal indicates correlation loss.
- Annotation Subsystem. The annotation subsystem contains the tick mark and fiducial generator and cathode-ray tube alphanumeric display for exposing data.
- Precision Photographic Restitutor Control Subsystem. This control subsystem provides for all internal sequencing of operations during open and closed loop modes of image processing. Commands and data are directed from the computer interface to the desired functional subsystem.
- Computer Interface. All communication with the central computer takes place through this functional subsystem.

3.7.10.2 Operational Performance

Operational performance characteristics are given in Table 3-8.

3.7.10.3 Annotation

Four fiducial marks and tick marks are printed at specified positions. Tick marks labels consisting of three-digit characters will designate latitude and longitude, in degrees. Special symbols may be considered as an alternative method of labeling.

Alphanumeric data will be printed on each processed frame in the area designated. A maximum of 384 characters will be printed.

3.7.10.4 Precision Photographic Restitutor Interface Requirements

Output. The precision photo restitutor system is capable of providing the following hard-copy outputs:

- RBV processed image, positive black and white master
- MSS processed image, positive black and white master
- RBV color composite, positive color master (one per set)
- MSS color composite, positive color master (two per set).

Input. Input images are negative masters produced by the laser beam recorder system, or contact printed negatives from laser beam recorder positive copies.

Operator Control. The precision photographic restitutor operator initiates the following actions:

- Turn machine on.
- Load input films and raw film
- Select printing slit
- Select black and white or color mode
- Switch precision photographic restitutor to ready mode
- Initiate rewind
- Unload film
- Service hardware or power failure actions, if required.

Table 3-8. Operational Performance of Precision Photo Restitutor

Input	9-1/2-in. roll film, 200 ft max
Output	9-1/2-in. roll film, 200 ft max
Master	9-1/2-in. roll film, 200 ft max
Printing modes	
Bulk	
Slit	0.811 by 0.05 in
Number of strips	10, including density wedge printing
Printing time	2.5 minutes per output print (including measurement of fiducials, printing image, and printing data)
Precision	
Slit	0.405 by 0.005 in.
Number of strips	19, including density wedge printing
Printing time	4 minutes per output print (including measurement of fiducials, printing image, and printing data)
Optical transformation	
Translation, Δx, Δy	±10 millimeters
Magnification	1.0 ± 0.05
Rotation	±2 deg
Distortion	Residual distortion less than 20 microns rms from all optical sources within the printing slit
Output MTF	In excess of 0.70 at 10 cycles/millimeter under normal operating conditions, assuming an input MTF of 1.0 at 10 cycles/millimeter
Correlation System	
Correlation	Continuous analog area correlation of input and master photographs during printing
Correlator outputs	x displacement error; y displacement error, magnification error; rotation error, correlation quality
Correlation accuracy	±60 microns rms at center of slit, bulk process
	±30 microns rms at center of slit, precision process
Scanning table drive	
x, y motion	10 in.
Printing rate	1 in./sec
Slew rate	3 in./sec
Setting accuracy	±30 microns rms
Quantizing error	±12 microns or less
Film drives	
Input and master	
Slew rate	30 in /sec
Frame position accuracy	±0.01 in. using edge detector sensing of gray-scale wedge
Rewind rate	30 in./sec
Output	
Slew and rewind	30 in./sec
Metering accuracy	±0.01 in.
Optical transformation drives	
Δx, Δy range	±10 millimeters
Δx, Δy setting accuracy	±30 microns
Magnification	1:0.95 to 1:1.05
Magnification setting accuracy	±0.3 percent
Rotation	±2 deg
Rotational setting accuracy	±0.1 deg
Fiducial measurement	Automatically measured on input and master frames by correlation with reference fiducial; accuracy, ±30 microns

Computer Control. The precision photographic restitutor will incorporate two 8-bit registers for communication with the central computer. Data transferred to the computer are 8- or 16-bit data words, or 8-bit instruction words. Instruction decoding is carried out in the precision photographic restitutor.

Discrete outputs from the precision photographic restitutor to the computer include:

- Power failure interrupt
- Hardware failure interrupt
- Strip complete signal
- Fiducial measurement complete
- Tick mark annotation complete
- Alphanumeric annotation complete
- Frame code interrupt
- Fiducial code ready.

Data words from the precision photographic restitutor to the computer include the binary frame code and the fiducial x, y coordinates.

3.7.11 Geodetic Control Measurement Station

The geodetic control measurement station allows an operator to simultaneously view the 9-1/2-inch RBV image and suitable maps on either 9-1/2-inch or 70-millimeter format to measure coordinates of selected image and map control points.

The photograph and map are illuminated simultaneously, and the operator may view selected areas through a binocular microscope, with variable magnification.

The geodetic control measurement station consists of the following items:

- x, y digital comparator, modified Optomechanisms, Model 527A
- Encoders and data logger, D. W. Mann, No. 1945

- Binocular zoom microscope (0.7x to 30x), Bausch & Lomb
- Photographic map library, Scales: 1:250,000, 1:62,500, 1:25,000; 70-millimeter roll film format.

3.7.11.1 Operational Requirements

The operational requirements of the x, y digital comparator are given in Table 3-9.

Table 3-9. Operational Requirements of x, y Digital Comparator

Illuminated areas	9-1/2- by 18-inch upper format 9-1/2- by 18-inch lower format
Intensity	Variable from 50 to 1,000 foot-lamberts; illuminated by encapsulated cold cathode light source
Reticles	Two (one for each format), on common support driven by x, y carriages
Measurement accuracies	±6 microns over format; repeatability to ±3 microns; resolution, 2.5 microns
Measuring encoders	Mann type, compatible with Mann data logger
Film loading	Top Upper, dual 70-millimeter film Lower, 9-1/2-inch film
Film transport	Upper and lower, 2-1/2 to 100 ft/min; 40:1 speed range; both directions motorized
Film flatness	Glass pressure plate, both formats
Fiducial alignment	Glass plate engraved with horizontal and vertical centerlines for simplification
Power requirements	100 volts, 60 cps at 10 amperes
Size	44-1/2 by 37 by 8 inches
Weight	Approximately 400 pounds (excluding microscope and base desk)
Color	Gray

.7.11.2 Interface Requirements

The data logger output is compatible with an IBM 026 card punch.

.7.12 Photographic Equipment

All of the processing equipment is commercial off-the-shelf hard- ʼare or has minor modifications therefrom. The following list of such quipment is included in the NDPF:

- Versamat black and white film processor
- Versamat color film processor
- 7.3- to 2-inch reducer
- Processing trays, 20 x 24 inch
- Print washer
- Print dryer
- Dry mounting press
- Print cutter
- Kodak rapid color film processor
- Processing trays, 10 x 12 inch
- Equipment maintenance set
- Black and white Log-Etronic printer
- Black and white Miller Holzwarth printer
- Black and white Durst enlarger printer
- Black and white Morse printer
- Color Log-Etronic printer
- Ekco Registration punch color printing
- Ekco registration board color printing
- Color printing point light source
- Itek densitometer
- Itek sensitometer
- Chemical analysis set
- MacBeth color analyzer
- Kodak sensitometric processor
- Richards light table
- Ekco pre-inspect/splice film handler
- Cleaner/waxer

- Copy camera
- Microfilm reader/printer
- Miscellaneous lab accessories
- Paper cutters
- Timers

4. Unified Display System —

CONTENTS

4. UNIFIED DISPLAY SYSTEM

The unified display system provides the basic man-machine interface in the computer-aided operations of the OCC and NDPF as described in Sections 2 and 3 of this volume. Requirements for man-machine functions and the tradeoff studies which led to the configuration described here are reported in Volume 15.

Digital television generation and distribution of computer-produced displays is the preferred mechanization for the GDHS. Intrinsic to digital television is its flexibility in both operations and growth while presenting an interface to the ADPE which is essentially that of more conventional display terminals. The principal elements of the unified display system are shown in Figure 4-1, and described in the following paragraphs.

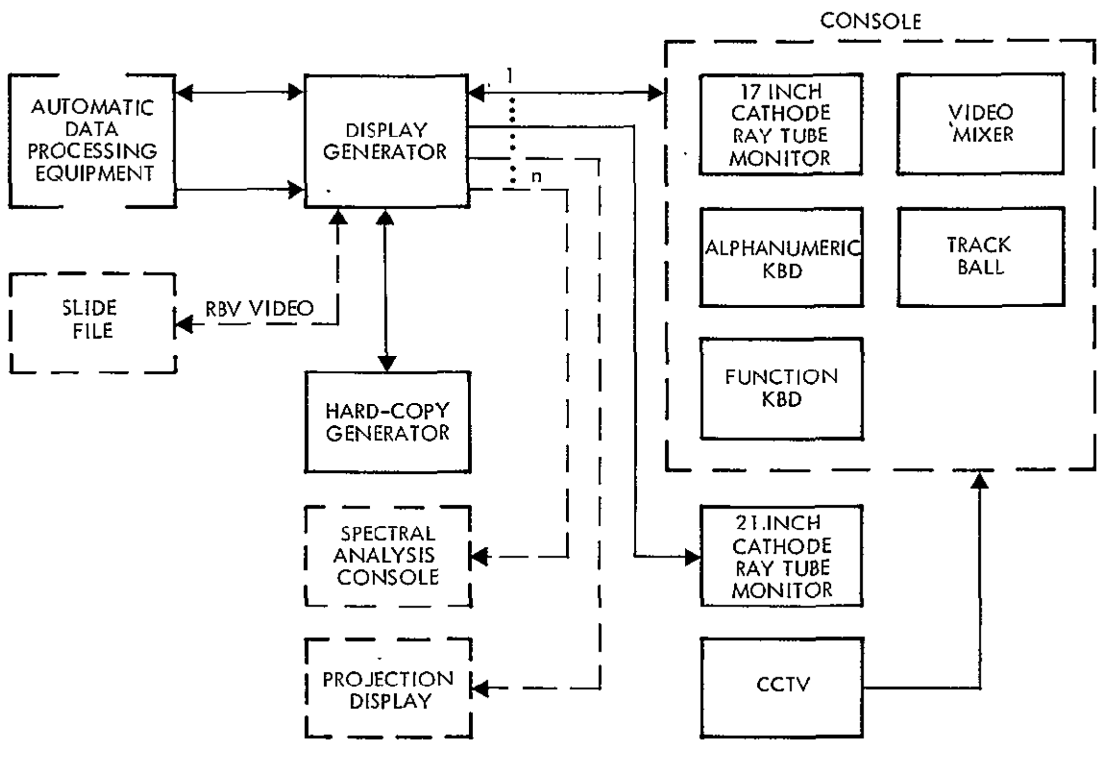


Figure 4-1
UNIFIED DISPLAY SUBSYSTEM block diagram

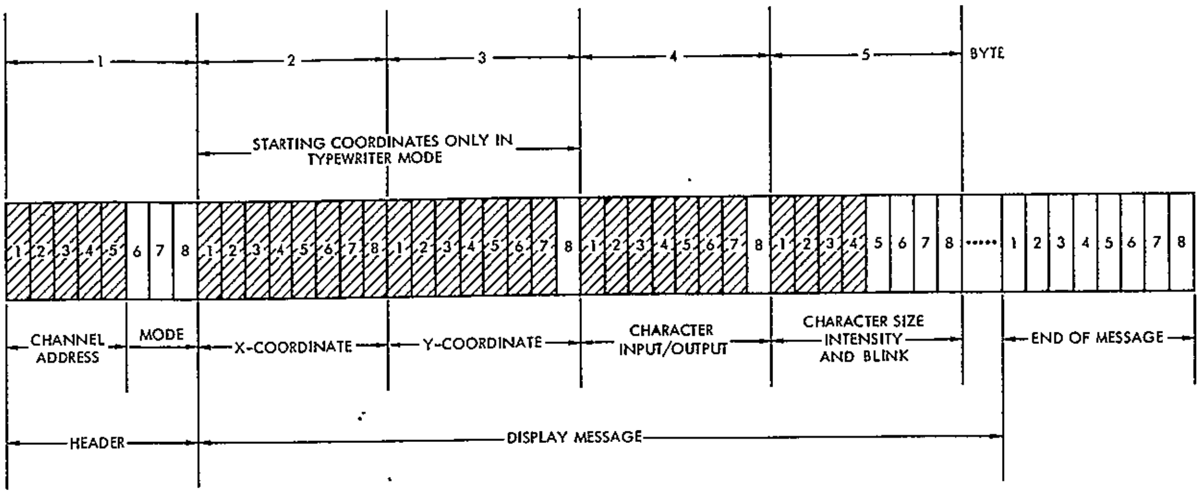


Figure 4-2
BASIC COMPUTER TO DISPLAY GENERATOR WORD STRUCTURE

4.1 DIGITAL DISPLAY GENERATOR

All display terminals are interconnected with the GDHS ADPE complex by means of the digital display generator. Each of the two central processing units in the ADPE communicates with the digital display generator through a data adapter unit (see Section 5). A complete image transfer requires not over 100 milliseconds to accomplish. The message from the ADPE to the digital display generator is typically organized as shown in Figure 4-2. The first byte (8 bits) addresses the specific display terminal or display generator output channel and also indicates the operating mode (typewriter, graphics, RBM/MSS video, function key enable). In the typewriter mode, the second and third bytes indicate the start-of-type address out of the possible 105 horizontal and 150 vertical small-sized character positions. Thereafter any one of 128 discrete character types is addressed by bytes 4 and 5 repeated successively. Character advance takes place automatically in the display generator including carriage return and line feed. Computer instructed line feed and carriage return can occur at any time by transmitting end-of-message byte containing a mode change bit to revert to computer control and continuing bit to revert to computer control and continuing therefrom until a true end-of-message is received causing a disconnect from the computer input-output channel. Each character identification is followed by 1 byte

which determines the character size (2 bits), its relative intensity (1 bit), and whether blinking should occur (1 bit).

When in the graphics mode, 4 bytes are required to characterize each character slot or position; these groups of four are repeated until the entire message has been transferred. The additional 2 bytes over those required in typewriter mode carry the x and y coordinate information for the selected character. This limited graphics mode permits a cost-effective design which has the capability of constructing graphics by means of special character vectors. An example of how this is accomplished is shown in Figure 4-3 through the use of a small number of special linear curve-fitting characters or symbols.

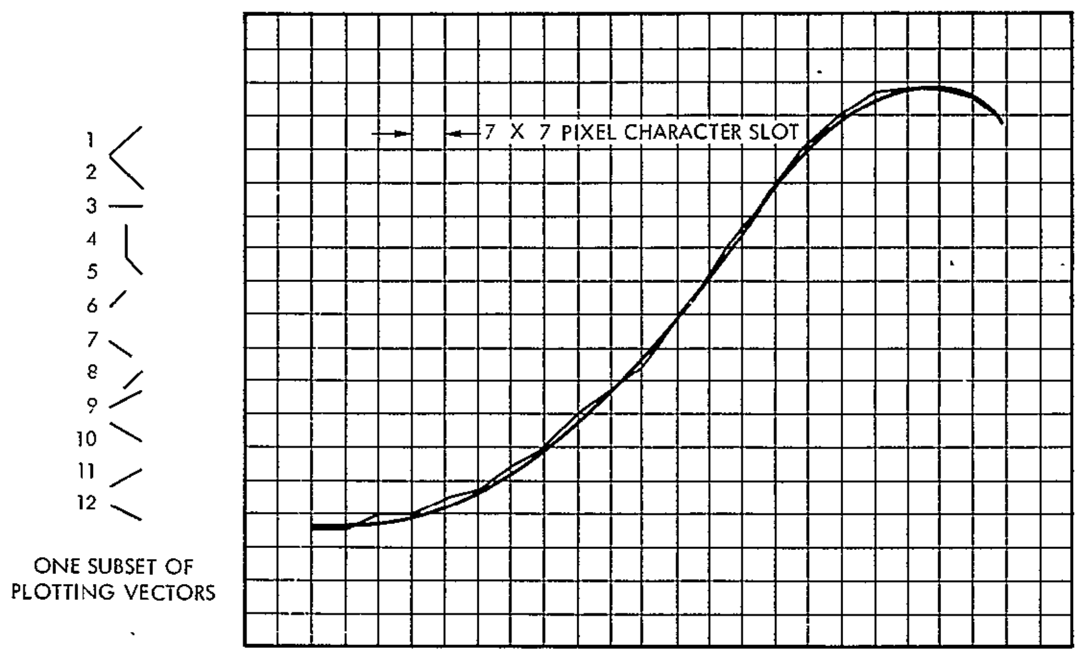


Figure 4-3
TYPICAL CURVE FITTING by limited graphics vectors

All characters are resident in a special symbol memory within the display generator and are read out on the fly into the reformatting and refresh memories under computer control. There are three character sizes. Each size of a given character is stored in the symbol memory as a separate character. Characters are composed on character slots which measure 7 by 7 pixels, 16 by 24 pixels, or 32 by 48 pixels. The

smallest slot is used only in the limited graphics mode. Figure 4-4 illustrates a typical character construction with relative dimensions as seen on the console screen. The symbol memory may be dynamically altered at any time under computer control, thereby permitting any desired special-purpose symbology to be created as required, retained or not, and any desired degree of curve-fitting to be determined by computer control. Blanking and unblanking signals are a part of each character as obtained from the symbol memory.

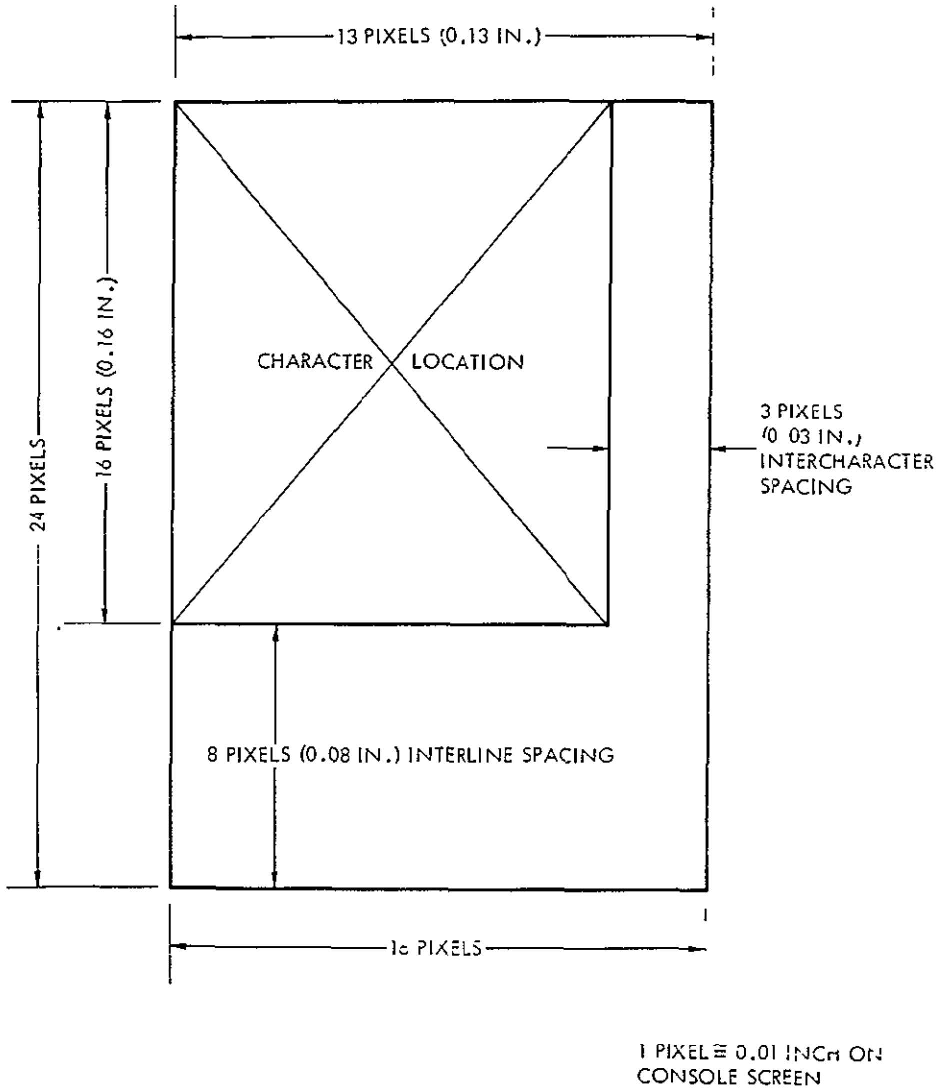


Figure 4-4

TYPICAL CHARACTER SLOT

In the function key enable mode, the header byte is immediately followed by three or more bytes required to carry the status data relating to the variable function keys on the console causing their activation and illumination. The end-of-message byte concludes this sequence as before.

When in the RBV/MSS video mode, the display generator receives a super-position of computer-generated data and a selected frame of RBV or MSS imagery as requested by the console operator. These signals are mixed or added in the wideband refresh buffer available for this purpose and made available to all consoles in the system. During the display of combined computer-generated data and RBV video, the former may be altered or updated as appropriate. Upon command from a console any portion of the RBV video image may be magnified by area factors of X4 and X16 as further explained below in the discussion of console operation. Equivalent full resolution display of MSS imagery is similarly provided.

The primary functions of the digital display generator are to accept and buffer, in individual channel refresh memories, the messages intended for the channel designated consoles or large-screen monitors after first reformatting the computer instructions into time-ordered serial bit streams which appear to the display terminals-to-be equivalent to line-by-line television video signals. In order to prevent undesirable vertical rolling during message changes and/or channel switching, synchronization is supplied on separate lines from the display generator to the display terminals. The display rasters are thereby locked regardless of changes in video content which may take place.

The scanning standards employed utilizes 1050 active lines (1127 total lines) at 30 frames per second with 2:1 interlace. Flicker is avoided by the use of a suitable screen in the cathode-ray tube displays which does not degrade the resolution and tonal range of the system.

Intensification and/or blinking of selected character slots is available as a means of attention accentuation or emphasis. These functions are ordered by bit instruction as described earlier. Blinking is accomplished by inhibiting or blanking a number of the refresh cycles for the so-ordered character slots so as to result in refresh rates of three to

six repetitions per second, but the exact number must be determined experimentally for any new system prior to being fixed in the design. Intensity emphasis is similarly determined experimentally and is implemented by dynamic amplitude control.

The major subsidiary function provided by the display generator is input message or edit buffering for interactive use of the console terminals. This feature permits the operator to compose, change, or edit any display on his screen without entry into the computer until he initiates such entry by operation of the appropriate function key.

4.2 CONSOLE AND LARGE SCREEN DISPLAYS

An illustration of the display console appears in Figure 4-5. It is 54 inches wide, 30 inches high, and 30 inches deep overall, exclusive of the swivel-mounted cathode-ray tube monitor assembly. All necessary provisions for complete man-machine interaction are incorporated into the consoles, all of which are identical. The console is configured as four functional groups: envelope, input, output, and communications.

4.2.1 Envelope

The console envelope is configured expressly to meet CDHS operational requirements (Volume 24 - OCC Subsystem, and Volumes 28 and 29 - NDPF Subsystems) for observatory command and control as well as for information and image processing management. The envelope is the structure supporting and containing the other functional groups. The unique design of the console envelope provides access to the display tube, cursor control, and program function keyboard, along with the utility of a desk surface. For detailed data entry using the alphanumeric keyboard, the operator relocates to the left of the console envelope, where he retains access to the program function keyboard cursor control and display tube. In addition, the envelope contains storage space, ashtray and cup retainer.

4.2.2 Input

There are three means of input to the system processors: alphanumeric keyboard, program function keyboard, and cursor control.

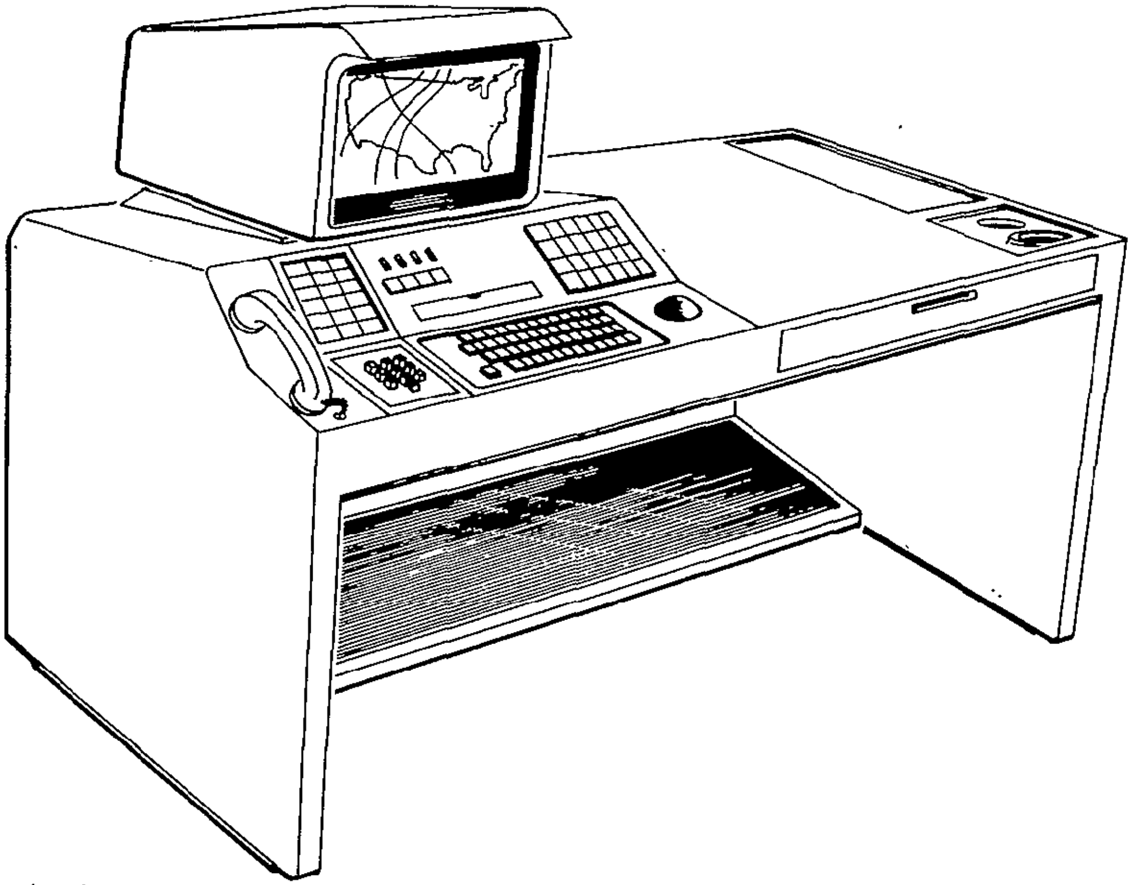


Figure 4-5
DISPLAY CONSOLE .

4.2.2.1 Alphanumeric Keyboard

The alphanumeric keyboard, similar in appearance to a typewriter keyboard, is used to input unique messages into the data processing system. These message functions include implementation of new software routines, command changes to the data base or data queries, or other input functions which are complex without severe time constraints. Each key inputs to the digital display generator which places that particular character on the display tube. When the entire message has been composed and visually verified from the display surface, an enable key is activated which now enters the message into the ADPE for processing, at which time the display is erased.

4.2.2.2 Program Function Keyboard

The program function keyboard is a group of buttons on the right side of the alphanumeric keyboard which are used to select preprogrammed instructions for implementation. The program function keyboard is used where standard or often used functions are requested, since a minimum number of key actions (one to five typically) are required to implement very complex instructions and routines. The program function keyboard is especially desirable for complex, time critical command implementation. The program function keyboard, through related automatic data processing equipment support software and key selection determines the functional relationship of each individual display console to the system. For example, a mnemonic key such as "COM," when enabled from the program function keyboard, provides all preprogrammed functions required for the observatory commander positions (or any other) without relying on a unique console or specific physical location. Reconfiguration of the console functions is accomplished with either a disable key or a changed mnemonic input. In addition to console configuration determination of command initiation functions, the program function keyboard is used to select display classes (command, housekeeping, trend, etc.), to disable or enable the alphanumeric keyboard or to institute frequent data base queries. The program function keyboard interacts directly with the ADPE. When an entry has been made, the activated keys are illuminated from a processor command, providing a verification signal to the operator.

4.2.2.3 Cursor Control

The cursor control provides positional coordinate data from the display surface (x-y) to the ADPE as well as providing a visual signal denoting this position to the operator. The cursor control is of the "trackball" variety providing coded position signals to the processor. Specific actions for functions related to the cursor position are determined by program function keyboard or alphanumeric keyboard inputs. For example, the cursor image is placed at a particular x-y coordinate; the program function keyboard is used to select a message input mode; the alphanumeric keyboard is used to generate the message with its initial character determined by the cursor position. The cursor can also be

used in conjunction with a displayed list of command or functions as an input adjunct. A visual list is generated, based upon stored commands, the cursor is placed on one entry, and an enable key activated which will initiate the function represented by the particular entry. The cursor can also be used in conjunction with imagery for annotation, placement, or image center selection for such operations as "magnify."

The cursor positioning device on each console is a track-ball which produces pulse trains in both x and y to indicate direction and degree of involvement. The sampling speed and pulse train rates are such that the operator may move his cursor symbol across the screen in approximately 1 second.

4.2.3 Output

4.2.3.1 Unified Display Console

Console output (computer to operator) is provided through a 17-inch diagonal cathode-ray tube monitor driven by internally synchronized signals from the digital display generator. Data is received from the ADPE, and placed on line interlaced format by the digital display generator, which also provides refresh memories for every display channel.

The display raster is 1050 active scanning lines, which is one-fourth of the available RBV line structure (nominally 4200) for the full frame; consequently a 50 by 50 nautical mile area can be displayed at one-half resolution, and a 25 by 25 nautical mile area can be displayed at full resolution as well as the full frame (100 by 100 nautical miles) at one-fourth resolution. This capability provides effective image screening and evaluation capabilities without either increasing system cost or requiring additional automatic data processing equipment support. The RBV square aspect ratio image is centered on the rectangular 4 by 3 aspect ratio screens. When MSS imagery is displayed, full revolution is obtained for a 40 by 40 nautical mile area and the full frame appears at 0.4 revolution due to the different MSS line structure.

The monitor assembly is mounted such that it can be rotated in either direction (left and right from center) to provide visual access from either the desk portion of the same console or from another position.

4.2.3.2 Large Screen Monitor

Four large screen monitors (21-inch diagonal) are mounted in the OCC to provide group access and contingency message (forced) displays. Since these monitors are also driven by the same display generator as the consoles, their scanning and resolution characteristics are similar. Each monitor has an independent channel, and consequently may have presentations unrelated to any of the other monitors. The large screen monitors are controlled from any single designated console. Designation is determined by the OCC manager and implemented through the particular program function keyboard.

4.2.4 Communications

The left side of the console contains push-button (touch) phone address as well as a communication select panel behind it. Enabling the particular select switch provides access to the GDHS intercom positions or the SCAMA II net. Both a headset and telephone are available to the operator.

4.3 VIDEO MIXING

In order to provide the capability to view display presentations originating from sources other than the display generator (i.e., CCTV), with identical scanning standards, a video mix capability is provided. This video mixing in effect provides a combined image to a given monitor based on multiple discrete inputs to the monitor.

In addition, the unified display system accepts and displays one frame at a time of RBV or MSS imagery from the NDPF formatted image tapes. The digital display generator converts the digitized imagery into a form suitable for presentation on the 1050-line monitors and transfers the prepared data to a disc refresh memory which is accessible from any display terminal.

4.3.1 RBV Processing

The digital display generator receives the 4200-line RBV signal in the same form as it is prepared for the laser beam recorder. Depending upon the expansion scale, the digital display generator performs a peak intensity detection of all data within the scale window and outputs the peak

value as the video representation of the element in the 1050-line raster. For example, at one-fourth revolution display of the full RBV frame, logic within the digital display generator accepts the encoded intensity data of the first four video elements of line 1 of the 4200-line image. Only the peak intensity of the first pixel out of 4200 contained in each line is transferred to intermediate memory. This continues until the entire first line is sampled. Lines 2, 3, and 4 are sampled on a similar manner and their intensity profiles are compared. The peak value out of each 4 by 4 cell is retained and transferred to the disc refresh memory to form the first line of the 1050-line display. The entire process continues for the remaining 4196 RBV lines. Peak video detection is used in lieu of averaging to avoid the possibility of one intensity cloud cover from obscuring data which may be visible in small breaks in the cover.

Similar processing takes place at the X4 scale setting except that the sampling matrix is 2 by 2. The X16 scale bypasses the sampling logic, transferring every line in the window to refresh memory. A winter loaded from the cursor register determines the start and stop points of the processing to permit subarea selection in accordance with the actions of the console operator.

Image magnification of the RBV data permits the operator the choice of the following

- X1: full screen display at 1050 active lines (one-fourth resolution).
- X4: full screen display at 1050 active lines of any one-fourth square area contained in the RBV frame (one-half resolution). The center of the area to be displayed can be selected by means of the cursor control.
- X16: full screen display at 1050 active lines of any one-sixteenth square area contained in the RBV frame (full resolution). The center of the area displayed is selected by means of the cursor control.

4.3.2 MSS Processing

Display of MSS frames is accomplished essentially in the same way described above for RBV images. A few differences in results occur due to the dissimilar MSS line structure (nominally 2640 lines). A maximum

of 2100 lines of the MSS frame are displayed on the full screen with accompanying revolution of one-half. This is accomplished by sampling with a 2 by 2 matrix as described above and covers an approximate area of 80 by 80 nautical miles. By cursor selection, the display can be off-centered to bring any portion of the 100 by 100 nautical mile frame into view. One magnification step permits any 40 by 40 nautical mile region of the MSS frame to be displayed at full revolution.

4.4 HARD-COPY GENERATOR

A hard-copy device capable of producing a permanent record of a given presentation on any of the 14 channels is an integral part of the unified display system. Since the hard-copy produced is a permanent record of a particular display presentation, a separate channel output from the display generator is not required. The requesting console in effect orders access of the hard-copy generator channel, and the hard-copy generator produces an image identical to that on the console monitor. The requesting console may not have a presentation frame update until the image scan has been completed by the hard-copy device. Average queue time (or wait) can be presented to the console operator, on request.

The hard-copy generator is a special version of the Singer-GPL Model 1983 printer. This unit was selected over several others for its two most desirable features, high resolution (in excess of 1050 elements in each direction), and intensity level repeatability of 10 levels.

The hard-copy generator interfaces with the digital display generator receiving video and sync signals and print request signals. In turn, it transmits back availability and status signals to control the processing logic in sequencing through any queue which may have formed during the last hard-copy print cycle.

The hard-copy generator produces prints 8-1/2 by 11 inches; positive or negative and the picture being printed is viewable as it is being printed.

4.5 BACKGROUND GENERATOR

In order to provide complex repetitive display backgrounds, a CCTV and slide file is utilized. A slide file containing up to 160 standard

35 millimeter transparencies in 2 by 2 inch mounts is accessed by a console keyboard.

Upon request from the console, the appropriate slide is retrieved from the slide file and scanned by a television camera. The resulting video signal is aligned to coincide with the digital display generator video and mixed with the digital display generator video for the requesting console. The output of the mixer is stored in a small buffer memory. When the memory is loaded, the data is transferred to the appropriate location in the digital display generator refresh memory. The resulting video presentation contains the computer-generated video superimposed on the background information retrieved from the slide file.

4.6 GROWTH CAPABILITY

The unified display system is designed to accommodate an increase to 20 output channels without modification to the basic system. Up to four display monitors may be driven from each channel, three of which then function as slaves. The inherent nature of order distribution permits placing terminals at long distances from the central equipment without complex data modems in the lines.

Electronic multi-spectral analysis may be performed by the addition of a multi-color console, otherwise identical with the basic console. The spectral analysis console permits a user to perform on-line heuristic determinations of optimal pulse color and gamma combinations of RBV or MSS imagery. The results of such actions are directly entered into the computer to alter image processing criteria in the NDPF.

CONTENTS

5. AUTOMATIC DATA PROCESSING EQUIPMENT (ADPE) CONFIGURATION*

There are two separate but interrelated segments of the GDHS that affect the design of a data processing configuration, i.e., the OCC and the NDPF. The OCC function is controlling and managing a complex and expensive spacecraft with a maximum assurance of its health and safety. The NDPF function is the generation of a large quantity of data that conforms as closely as possible to user requests and is of a quality compatible with the users' needs.

NASA and its contractors have accumulated several years of experience in the operation of orbiting spacecraft that are comparable in complexity to the ERTS. This experience indicates that trends leading to catastrophic failure of the spacecraft can be detected and corrected by manual (i. e., non-ADPE) techniques, but that efficient operation of the spacecraft and sensors requires computer support for mission planning, scheduling, and command generation. Since a computer is necessary for adequate normal operations, it is obviously desirable to use the same computer to improve the spacecraft monitoring and control functions. The consequences of a computer failure would be a serious bottleneck in the data flow, and possibly a serious threat to the safety of the spacecraft; this fact has direct implications on the design of an ADPE configuration, especially in the provision of redundant or backup computer capability.

5.1 OCC/NDPF COMPUTER SYSTEM DESCRIPTION

Considering the functional characteristics of the OCC and the NDPF, two computer systems are proposed: an IBM System 360/44 for the OCC,

*The selection of the IBM 360/44 and 360/85 for the GDHS is based on the ADPE procurement described in Volume 18 of our final report. Because this procurement was carried out in parallel with the system design, optimization of the selected ADPE configuration and the interface between this equipment and the elements of the GDHS that it services has not been completed. This is now being done with the selected contractor, the Data Processing Division of IBM. We anticipate significant cost savings from this effort due to reduction and simplification of automatic data processing peripheral and GDHS special-purpose interface equipment. The functions to be carried out and performance required will not be affected.

and an IBM System 360/85 for the NDPF functions. The two central processing units configuration is presented in Figure 5-1. The essential feature of this configuration is the interfacing of the two computer systems in a channel-to-channel sense. The individual central processing units are not linked.

The OCC system has no dedicated peripheral devices, but rather shares such devices with the NDPF computer system. The OCC system has access to four of the 10 available magnetic tape units through an operator-controlled switch (2911). The IBM System 360/44 uses this feature during software and system checkout, but rarely, if at all, during observatory servicing. A printer and card reader/ punch are shared, as required, between the two systems through a programmable switch (8100). A direct access storage device (2314), which is shared by both systems through a programmable switch (8100), is provided for OCC system backup by the NDPF computer. The common residence of data and software routines required for observatory support in the event of OCC computer mainframe failure, resides in this unit. Under these conditions, an operator-controlled switch interfaces the NDPF computer system and the command data interface unit for transmission of observatory commands generated within the NDPF system and with the PCM unit for receiving and processing telemetry data. Displays are operable from either system through a common buffer.

The NDPF system has access to all peripheral devices, those dedicated to it as well as the shared units discussed above. Two of the six magnetic tape units dedicated to the IBM System 360/85 are seven-track, 800 bytes/in. drives for users without nine-track capability. The shared direct access storage device (2314) is used by the NDPF system for information management and production control files in addition to the common data base indicated above. Two fixed-head discs are dedicated units on the NDPF system for high-speed storage and transfer of image data from the RBV and MSS reproducer units. The salient features of the two proposed computer central processing units and descriptions of individual hardware units are presented in the following subsections.

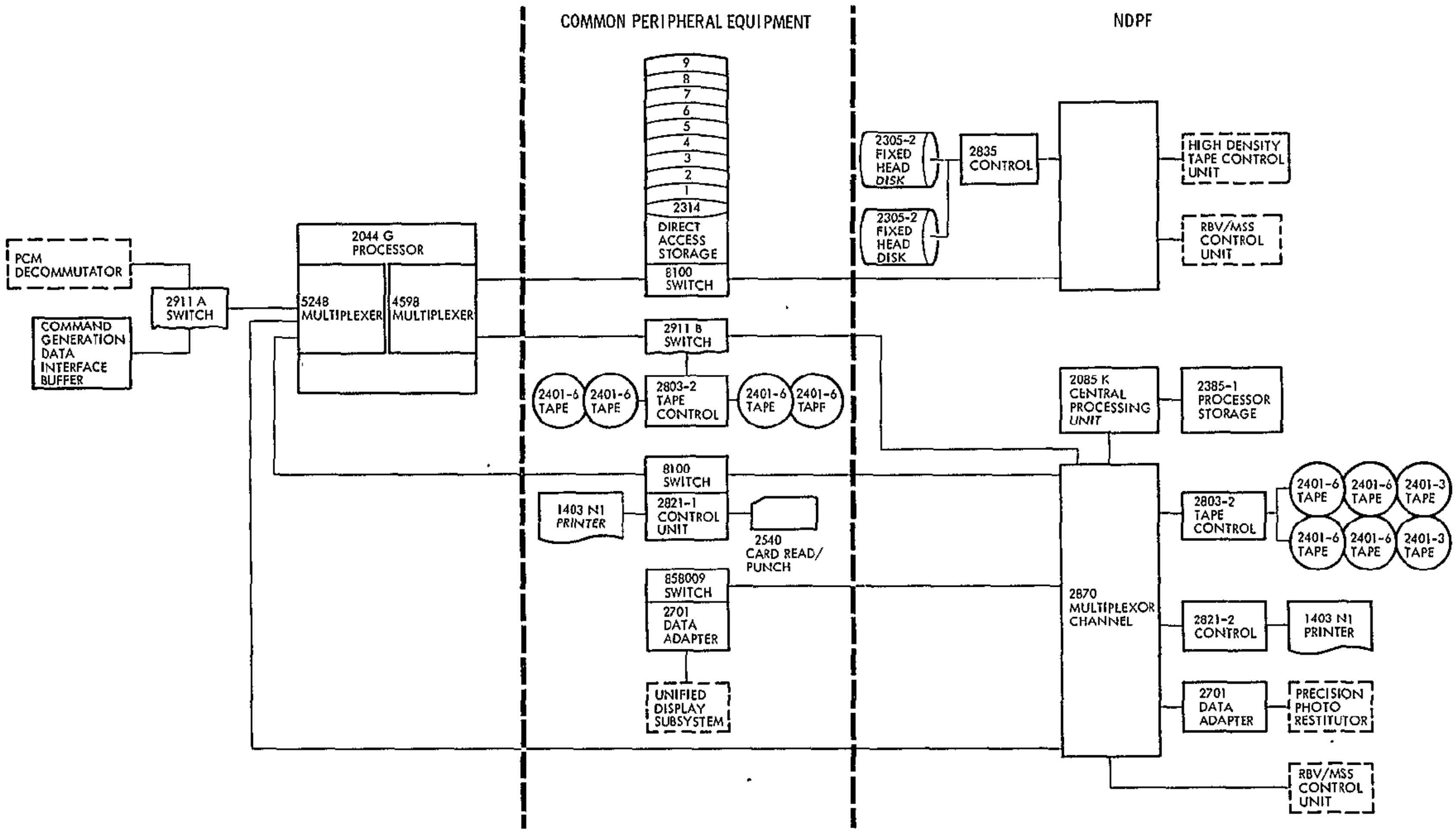


Figure 5-1

GDHS-ADPE CONFIGURATION COMMON PERIPHERAL EQUIPMENT

5.1.1 OCC Computer System

The IBM System 360/44 is tailored to handle all relatively small- to medium-sized scientific applications and advanced data acquisition and process control applications. Although the Model 44 is thus specialized, its inclusion within the context of System 360 philosophy provides for a very large addressing capability, a wide range of high-speed storage capacities, and input/output multiplexing on channels of low and high data transfer rates.

The basic Model 44 is unilaterally compatible with System 360 Models 30 through 91. That is, a program written for the Model 44 can be executed on any of these other models if the compatibility constraints of System 360 are observed. However, programs that depend on special features available for only the Model 44 cannot be run on any other System 360 model.

Model 44 was derived from standard System 360 architecture by including only those capabilities and instructions that are required for a binary and scientific model. It therefore excludes 19 instructions that are normally included in the standard instruction set; those excluded are decimal arithmetic and other variable-field-length instructions.

One or more multiplexer channels, providing a choice of two data transfer rates, can be included in the system. (Model 44 cannot be equipped with selector channels; however, a multiplexer channel in which one of its subchannels is operating in burst mode performs very similarly to a selector channel).

Model 44 uses conventional high-speed sequential logic control instead of read-only storage.

Although the processing unit is about the same in physical size as that of its nearest neighbor, the Model 50, its performance on problems for which it is optimized is 30 to 60 percent faster than that of a Model 50. Performance figures depend much on the specific applications and optional equipment selected, namely: storage size, number and speed of channels,

and quantity and speed of input/output devices supporting the central processing unit.

Standard Features

- Universal instruction set
- Console printer keyboard
- Single-disc storage drive
- Timer

Optional Features Being Installed

- Floating point instruction set
- High-speed general registers
- Protection (store and fetch)
- Commercial feature
- Multiplexer channel
- High-speed multiplexer channel
- Priority interrupt
- External interrupt

5.1.1.1 System Components

Central Processing Unit: 2044 Processing Unit. The basic machine cycle time is 0.2 microsecond (200 nanoseconds).

The universal instruction set is standard with the Model 44. The 16 general registers of the basic Model 44 are in a normally-unaddressable extension of the 1-microsecond processor storage. The optional high-speed general registers feature provides the 16 general registers with solid logic technology circuitry having 0.25 microsecond read/write time. This quartering of the access periods substantially reduces address generation time as well as the basic execution time of all fixed-point instructions in particular.

Main Storage: G Processor Storage. Storage size is as follows:

Capacity (Bytes)	Model	Storage Cycle Time	Storage Access with
131,072	G	1 μsec	4 bytes

Both store and fetch are optional as a protection feature.

The Model G processor storage is adequate for the present configuration. However, upon further study, if it seems appropriate to increase the storage, a Model H processor storage of 262, 144 bytes will be substituted for the Model G.

4598 High-Speed Multiplexer Channel. The 4598 high-speed multiplexer channel provides for the attachment of high-speed input/output control units and associated devices.

The high-speed multiplexer channel has one subchannel which can accommodate two control units. The high-speed multiplexer channel can overlap the operation of the input/output devices in multiplexer mode or operate a single device in burst mode.

5248 Multiplexer Channel. The 5248 multiplexer channel provides for the attachment of a wide range of low to medium speed input/output control units and associated devices.

The basic multiplexer channel has eight control units and can address 64 input/output devices. The basic multiplexer channel can overlap the operation of several input/output devices in multiplex mode or operate a single device in burst mode.

5.1.2 NDPF Computer System

The System 360/85 provides increased precision, speed, and storage capacity beyond that of Models 65 and 75. The precision of scientific computations is significantly increased by extended-precision floating-point arithmetic; the speed of operations is increased by four-way interleaving, the high-speed multiply feature, and a unique high-speed buffer storage. The maximum main storage capacity of 4,194,304 bytes,

four times that of the Model 65 or 75, makes the Model 85 well-suited for effective and efficient multiprogramming.

The performance of this system is further enhanced by notable reliability features, such as the instruction retry feature, the recovery management support program, and the main-storage error-checking and correction circuits.

Standard Features

- Universal instruction set
- High-speed buffer storage (16,384 bytes)
- Extended-precision floating-point arithmetic
- Instruction retry
- Error checking and correction
- Storage protection (both store and fetch protection)
- Byte-oriented operand
- Attachments for 2860 selector channel and 2870 multiplexer channel
- Direct control (includes external interrupt)
- Timer (line-frequency type)
- Microfiche document projector and viewer

Optional Features

- 2880 block multiplexer channel
- High-speed multiply
- Buffer storage expansions (as many as two, each with 8,192 bytes)
- 2860 selector channel (as many as two units, providing as many as six selector channels)
- 2870 multiplexer channel
- Selector subchannels (as many as four)
- Channel-to-channel adapter

5.1.2.1 System Components

Central Processing Unit: 2085 Processing Unit. The basic machine cycle time is 0.08 microsecond (80 nanoseconds).

The universal instruction set is standard with the Model 85 high-speed buffer and its expansions. This unique storage feature permits a reduction of the effective system storage cycle time to as little as 80 nanoseconds if the desired data has already been transferred to buffer storage. Total buffer storage available (with expansions) is 32,768 bytes.

The operations of the central processing unit's instruction and execution units are overlapped, allowing execution of instructions to proceed while the instruction unit prepares for later operations.

Main Storage: 2385 Processor Storage Model 1. Storage size is as follows:

Capacity (Bytes)	Model	Storage Units	Type of Interleaving
2,097,152	K85	One 2385-1	Four-Way

Storage cycle time is 0.96 microsecond for the 2385 Model 1. (The effective storage cycle time is sharply reduced if the data has already been transferred to buffer storage.) Storage access width is 16 bytes (one quad-word). Both store and fetch protection are standard.

5.1.2.2 Channels

Channels provide the data paths and direct control for input/output control units and the input/output devices attached to the control units. Channels relieve the central processing unit of the task of communicating directly with the input/output devices and permit data processing to proceed concurrently with input/output operations.

Data is transferred one byte at a time between an input/output device and a channel. Data transfers between a channel and the storage control unit are parallel by eight bytes for both selector and multiplexer channels.

A standard input/output interface provides a uniform method of attaching input/output control units to all channels.

A 2860 selector channel and the 2870 multiplexer channel is provided for the Model 85, and a 2880 block multiplexer channel is also available.

The adapter permits the communication between two System 360 channels, thus providing the capability for interconnection of two processing units within System 360. The adapter uses one control unit position on each of the two channels. Only one of the two connected channels requires the feature. There can be a maximum of one channel-to-channel adapter per channel.

2870 Multiplexer Channel. The 2870 multiplexer channel provides for the attachment of a wide range of low- to medium-speed input/output control units and associated devices.

The multiplexer channel provides up to 196 subchannels, including four selector subchannels. The basic multiplexer channel has 192 subchannels; it can attach eight control units and can address 192 input/output devices. The basic multiplexer channel can overlap the operation of several input/output devices in multiplex mode or operate a single device in burst mode. One to four selector subchannels are optional with a 2870. Each selector subchannel can operate one input/output device concurrently with the basic multiplexer channel. Each selector subchannel permits attachment of eight control units for devices having a data rate not exceeding 180 kilobits. Regardless of the number of control units attached, a maximum of 16 input/output devices can be attached to a selector subchannel.

The maximum aggregate data rate for the multiplexer channel ranges from 110 to 670 kilobits depending on the number of selector subchannels installed. Selector subchannels 1 to 3 may each operate concurrently at up to 180 kilobits; selector subchannel 4 has a maximum data-rate of 100 kilobits. Each selector subchannel in operation diminishes the basic multiplexer channel's maximum data-rate of 100 kilobits.

2880 Block Multiplexer Channels. The 2880 operates in either the selector channel mode or the block multiplexer mode. Selector channel mode is functionally equivalent to the 2860 selector channel operation. The block multiplexer mode permits the concurrent operation of up to

64 input/output devices on a single channel by multiplexing blocks of data on the single data path of the channel. New reliability features provide for extensive checking of channel and control unit operations, and on certain failures, provide automatic hardware retry of malfunctioning operations.

Additional data buffering provides lower system interference. The basic 2880 is capable of data rates up to 1.5×10^6 bytes/sec.

5.1.2.3 Direct Access Devices

IBM 2314 Direct Access Storage Facility Models 1, A1, and A2. The IBM 2314 direct access storage facility contains a control unit and up to eight independent disc storage drives. A ninth drive is provided to be used if one of the eight normally addressed drives requires preventive or emergency maintenance.

The maximum, average, and minimum access times for the 2314 are 130, 60, and 25 milliseconds. Average rotational delay on all models is 12.5 milliseconds. Each drive in the 2314 operates independently. The 2314 use the removable disc pack method of storing data. The data rate of the 2314 is 312,000 bytes/sec.

Each disc pack in the 2314 has a capacity of 29.17 million bytes (or 58.35 million packed decimal digits and signs). Each of the 20 disc recording surfaces is divided into 200 concentric tracks; each track has a capacity of 7,294 bytes.

The discs of the 2314 are composed of 20 tracks, one on each disc surface. With 7,294 bytes per track, 145,880 bytes are available under each of the access mechanisms in a 2314. Within a cylinder, multiple records can be read or written by command chaining, without rotational delay between records.

The eight removable and interchangeable IBM 2316 disc packs required by each 2314 provide a total of 233.4 million bytes of on-line disc storage and practically unlimited off-line storage.

File scan and record overflow are standard features. File scan permits a comparison on selected bytes (in effect, a search through the

file for a specific record or condition). Record overflow increases the utilization of storage by allowing a record to overflow from track-to-track to the end of the cylinder.

2305 Fixed Head Storage Facility and 2835 Storage Control. The 2305 fixed head storage modules physically consist of a nonremovable rotating media and multiple element recording heads. The recording media consist of six discs revolving in an environmentally controlled air system. The 2305 Model 2 has 768 tracks, each with its own read/write head and a maximum capacity of 14660 bytes per track.

Record overflow, multiple track operation, multiple requesting, and rotational position sensing are all standard features. The rotational position sensing function enables the channel to seak an angular track position. It permits channel disconnection during most of the rotational latency period and thus contributes to increased channel availability.

A two-module 2305 Model 2 fixed head storage facility has the ability to store 22×10^6 bytes of information.

2835 Storage Control. The 2835 storage control provides the capability of attaching two 2305 fixed head storage facilities to a 2880 block multiplexer channel for a total on-line direct access capacity of more than 22×10^6 bytes. The 2835 interprets and executes all control orders received from the channel and checks the validity of the data transferred to or from the storage devices.

5.1.2.4 Tapes

IBM 2401 Models 3 and 6 magnetic tape unit; IBM 2803 Model 2 tape control. The IBM 2401 magnetic tape unit reads or writes nine tracks across half-inch wide, heavy-duty magnetic tape at a density of 800 or 1,600 bytes/inch (bpi). Each byte contains one letter or special character, or two 4-bit decimal digits, or one decimal digit and a sign, or eight binary bits, etc., and a ninth bit used for parity checking.

The model numbers designate the type unit speed in bytes/sec, which is directly related to two factors: tape speed in inches/sec, and data density in bytes/inch of type.

Model 3 90, 000 bits/sec at 112.5 inches/sec at 800 bytes/inch

Model 6 180, 000 bits/sec at 112.5 inches/sec at 1, 600 bytes/inch

Model 6 uses the technique of "phase encoding" for its advantages of high-speed and automatic single-track in-flight error correction.

The 2803 controls as many as eight tape units and is in two models. Model 2 is primarily for control of the 1,600 bytes/inch units of the 2401 Model 6, but may also control 2401 Model 3, 800 bytes/inch tape units since both the nine-track compatibility feature and the seven- and nine-track compatibility feature is installed. (Also each 2401 Model 3 attached to Model 2 of the 2803 must have the mode compatibility feature.)

Controls attach to a selector or multiplexer channel and operate in the burst mode. A 2803 requires a control-unit position on the channel.

An optional seven-track compatibility feature enables a 2401 Model 3 to write or read seven-track tape at 200, 556, or 800 characters per inch; this provides tape compatibility with devices such as IBM 729 and 7330 magnetic tape units. The seven-track compatibility feature can be installed on any tape control and is required if any attached tape unit has the seven-track head. As part of the seven-track compatibility feature, a code translator feature is included to translate the BCD interchange code to the System 360 code (EBCDIC).

5.1.2.5 IBM 2701 Data Adapter Unit

The IBM 2701 data adapter unit provides for the on-line connection to System 360 of a variety of local and remote systems and devices.

Eight 2701's can be attached to a System 360 channel, each occupying one control unit position.

Each 2701 provides for the attachment of up to four parallel data acquisition devices (word width of 16 to 48 bits).

All necessary bit-byte and word-byte conversions, interface matching, and data control for the attachment of specific terminal devices is accomplished by the 2701.

5.1.2.6 IBM 2540 Card Read Punch

The IBM 2540 card read punch reads cards at a maximum rate of 1,000 per minute and punches cards at a maximum rate of 300 per minute. The card reading and punching sections are separate entities, and reading and punching can take place simultaneously.

5.1.2.7 1403-N1 Printer

The Model N1 operates at higher speeds through the use of the universal character set.

The printer is controlled and buffered by the 2821 control unit, which also provided the attachment to a System 360 channel. One or two 1403's can be controlled by each 2821, depending on the 2821 model.

The Model N1 uses an interchangeable chain cartridge adapter. The cartridge adapts the 1403 for quick and convenient changing of type fonts or character arrangements for special printing jobs.

Characters are printed 10 to the inch, and lines are spaced either six or eight to the inch under operator control. Auxiliary ribbon feeding feature is standard.

The 1403 Model N1 features sound-absorbent covers extending to the floor, power-operated front and top covers, and a newly designed forms cart.

5.1.2.8 2821 Control Unit

The 2821 Model 1 and 5 control units interfaces 2540 card read punches and 1403-N1 printers to the System 360. It interprets and executes all control orders received from the channel. The 2821 Model 1 controls one 2540 card read punch and one 1403-N1 printer. The 2821 Model 5 controls one 2540 card read punch and two 1403-N1 printers.

5.1.2.9 2911 Switch control and 8100 Switch Feature

The 2911 provides a switching capability under operator control for those devices which will be accessed infrequently and at predetermined times by the System 360/44 or 85.

The 8100 switch feature provides a switching capability under program control in normal operation. A manual override capability is also included that can be activated by the operator.

5.2 LOAD SHARING

During Phase B/C, functions were defined for the OCC and the NDPF computer systems. These functions were further refined into software components (modules and routines) and their associated data flow and central processing unit execution support requirements. The results of this study are presented in Volume 16 (GDHS Study - OCC), and Volume 18 (ADPE Procurement) of the Final Report.

The OCC and NDPF facilities, by nature of their functions, give rise to two different modes of computer operation.

The OCC operates in a real-time sense during an observatory pass over the NTTF and in a near-real-time sense during other station passes. During non-pass time, the OCC computer system performs next revolution scheduling and command functions.

The NDPF operates in a batch processing mode. Bulk and requested image processing will be scheduled as will the associated functions of attitude computation and information management, but will be necessary to interrupt the main processing stream for production control queries and display servicing.

The real-time nature of the OCC operation generates the requirement for a backup computing capability in the event of a failure of the OCC computer system. This backup is accomplished in the following manner.

- The OCC and NDPF systems will be of the same model series produced by the same manufacturer
- The two computer systems will be configured to share a common random access storage device
- Both computer systems will have access, through a switch under operator control, to the command data interface unit and PCM data interface unit.

The first consideration assures with proper preplanning a software compatibility between the two computer systems in an object code sense rather

than a weaker source code sense. As such, software routines normally run on the OCC system can be run on the greater capability NDPF computer system, should the need arise.

The second point provides for the residence of critical OCC software routines within the NDPF computer systems fetching capability. Hence software routines can be loaded into the NDPF system central processing unit directly. More importantly, the shared random storage provides residence of the OCC data base parameters necessary for the software to function. Such data could be made available in other ways, but not within the time of a station pass.

The last item provides for communication to the observatory of commands generated on the NDPF system in the event of the OCC central processing unit failure.

The real-time character of the OCC operation and backup considerations naturally give rise to a priority interrupt capability which will be serviced by the operating system software and by computer hardware. In addition, the hardware will be run in a multiprogramming mode to support the above type of operation plus the interactive display communications. The NDPF system exhibits a similar need for multiprogramming, due to large amounts of data per image with resultant input/output bounding and interactive display considerations.

CONTENTS

6. COMPUTER SOFTWARE

The software for the GDHS is described in this section. Following the introduction, Section 6. 2 describes the software design for the operations control center (OCC) considering the studies of Volume 15 – GDHS Study, and Volume 16 – GDHS Study: OCC. Section 6. 3 describes the software design for the NASA data processing facility (NDPF) considering the studies of Volume 15 – GDHS Study, and Volume 17 – GDHS Study: NDPF. The designs of Sections 6. 2 and 6. 3 reflect Volume 18 – ADPE Procurement and depict the functions, modules, and routines. The software specification (Milestone B) is found in the Appendix to this volume.

Section 6. 4 presents the organization of the GDHS operating system required to support the software and capsule descriptions of all software elements in the routine level. The operating system, specific to ERTS, is described in this section.

6. 1 INTRODUCTION

The applications software of the GDHS accepts user requests for imagery or data and provides the imagery by reproducing either existing ERTS data or schedules observatory and processing activities to gather and process the data. Since the ERTS system provides the capability for generation and manipulation of massive amounts of data, careful design and allocation of the software identified in the functional analysis (see Volume 15) is required for efficiency in number of operators and operator time while still providing operator control. The primary software functions are:

- Operating system
- Data management

  File structure
  File maintenance
  Retrieval
  Output

- PCM telemetry processing

- Image processing

  Digital image processing
  Analog image processing
  Displays

- Production control

  Scheduling
  Data accounting

- Attitude determination
- Observatory utilization planning and scheduling
- Sensor coverage evaluation
- Command generation and validation.

Since the OCC operates 24 hours a day, 7 days a week, and the NDPF operates 8 hours a day, 5 days a week (in case A) those software functions used for full time operational support or real-time processing are assigned to the OCC and the remainder to the NDPF. PCM telemetry processing has been separated into nonintersecting subsets with the preprocessing of the real-time and the non-real-time PCM telemetry performed in the OCC and the annotation and data base generation performed in the NDPF.

The operating environment is an interactive system in which the majority of the work is performed by or under the direction of automatic processing techniques. The OCC applications programs require a system with performance and capacity to support real-time and near real-time operations, decision-making and observatory command/control besides general-purpose data processing services. The NDPF applications programs involve relatively high central processing unit utilization to iteratively process large quantities of data. During such processing, the demands for control program services and system control are small, although control program services, access to the data base, display device support, and utility processing are needed.

Since the NDPF is primarily concerned with data processing, a multiprogramming environment is used to provide for the dynamic concurrent scheduling of a variable number of software jobs within the central processing unit to increase total system throughput. Although separate computers are used for the OCC and NDPF, there are no major differences in operating system requirements and the identical executive is used in both facilities. The operating system for the OCC/NDPF performs the following functions:

- Monitor all computer usage
- Control the allocation of system resources
- Initiate the processing of individual jobs in a job stream
- Control all input/output activities
- Provide the operator with interactive control and display
- Manage files of user data
- Perform the accounting for the use of various system resources,

and provides the following services:

- Support processors such as assemblers, compilers and pre-execution analyzers
- Utilities to alter, manipulate and retrieve the contents of user data files
- Library services for the fast retrieval of commonly used subroutines and programs.

In brief, the OCC software functions are:

- Observatory scheduling
- Command generation
- Command message update
- PCM telemetry preprocessing (limit check, conversion to engineering units, further processing in the NDPF)
- DCS data (gross limit checks only)
- Sensor coverage evaluation.

The NDPF software functions are:

- Precision attitude and coverage determination
- Generation of PCM telemetry and DCS data bases (including DCS annotation)
- Information management
- Digital image processing
- Image processing support.

Even the most careful definition of the OCC/NDPF interface requires a very small amount of overlap. For instance, a rather rough attitude determination is performed in the OCC sensor coverage evaluation function in order not to reschedule areas for which adequate imagery exists while more accurate attitude determination is performed in the NDPF. In case of failure by the OCC computer, the NDPF computer may be used as a backup for the real-time activities. This capability requires common access to the data base, display system and telemetry hardware by both computer systems, plus dual loading ability for OCC applications programs.

The NDPF provides the interface with the user since the NDPF receives user requests for imagery. A file search is made to determine if imagery of the desired area and quality is available. If such imagery is available, it is reproduced and disseminated. If the requested imagery is available but is not in the desired quality, precision processing is initiated in the NDPF. Should imagery covering the requested temporal or spatial conditions not be available, the OCC is notified of such requests. These requests are inputs to the non-real time OCC applications software.

6.2 OCC SOFTWARE

The nonreal-time OCC software may begin generating command loads many days before a pass or may, under the most urgent conditions, begin only a few hours before the scheduled pass. In any case, user requests for sensor coverage are examined by the observatory scheduling function and an event list is generated. Such a list could contain sensor

events for RBV and MSS sensor coverage, and manually entered orbit adjust events, ground station communication events, and wideband tape recorder events of sensor coverage, etc. Upon completion, the event list is displayed to the operator for his approval. Should he wish to make changes, he may do so manually before the observatory scheduling function calls the ground facilities scheduling function to request ground station support at the required times.

A command list is prepared next by the command generation function which accepts the events list together with manually input commands. The command list is a schedule of the actual commands to be sent to the observatory together with the time of transmission and, in the case of the stored command programmer commands, the planned execution time. This list is displayed to the operator, who can input changes to it. When the operator is satisfied that the command list is correct, he may prepare a punched paper tape of the command list and transmit the list to one or more remote stations via teletype or NASCOM to act as a backup command station. He also saves the command list for real-time-commanding from the OCC.

The command message update function is run to predict the vehicle status at the future time of execution and at the time of the real-time pass following execution to ascertain, in real-time, that the vehicle and its payload have performed as desired. This function determines and outputs a complete executed command history for the spacecraft and payload after the spacecraft narrowband data and real-time telemetry have been stored.

After the pass, the sensor coverage evaluation function determines the executions that took place. From the executed command history, this function determines the shutter events. From this list of shutter events, the corner coordinates of the frames taken are determined based on nominal vehicle attitude and fed back to the observatory scheduling function to delete expected successful take from the sensor coverage request list.

A second mode of operation of the OCC applications software is real-time acceptance of telemetry, real-time spacecraft commanding

and real-time command verification. Real-time conditions are defined as follows:

- Either prestored or manually generated real-time commands are sent to a remote station and then to the spacecraft from the OCC for immediate execution
- Either prestored or manually generated stored program commands are sent to a remote station and then to the spacecraft from the OCC for later execution
- Verification of the execution of real-time commands
- Verification that the stored commands have been received and stored properly by the spacecraft
- Telemetry processing and display to support the above functions and to keep the operator informed of the status of the spacecraft, payload and other equipment.

During real-time operations portions of three software functions reside in core storage. These are the real-time portions of the PCM telemetry processing, command generation, and command message update functions. Just prior to the real-time pass this software is loaded into core memory and execution initiated. When the real-time telemetry begins to arrive at the OCC, the software initiates processing. Telemetry is processed one mainframe at a time, each mainframe containing 1152 bits of information. Initially, the PCM telemetry processing function is in control with an outstanding read instruction for the first mainframe to be read into one portion of a double buffer. When the buffer is full, the data line is switched by software to the other buffer and processing begins on the first buffer. This processing provides conversion to engineering units, combination or averaging parameters, and limit checking. Parameters are displayed and those not within prescribed limits are flagged for attention to the operator. The operator may at his option change the prescribed limits. The mainframe data, smoothed and converted to engineering units, is stored on a historical tape for later use by the NDPF. Additionally, up to 10 parameters are stored for fast access for real-time or post-pass trend analysis. One further task of the PCM telemetry processing function is to compare each telemetry mainframe with its

predecessor and store those parameters which have changed in a working buffer. After the telemetry processing is complete, control is passed to the command generation function.

The task of the command generation function during real-time operations involves real-time commanding and command transmission to the spacecraft. When command generation operates, the list of prestored real-time commands is scanned to determine if it is time to send a command. If so, the operator is interrogated for his permission to enable transmission. The operator may compose a command to be transmitted. When the operator's permission is granted the command validation process begins. This process consists of communication between the command generation function and the remote station via NASCOM transmission facilities. For STADAN stations, the command generation function transmits the command to the station and the station returns the command to the command generation function. The command generation function performs a bit-by-bit comparison of the transmitted and received messages. If comparison shows no errors, the command generation function orders the remote station to transmit the command to the spacecraft. For MSFN stations, the command generation function encodes the command in a special way appending an error code. The station decodes the command, and if the error code checks, returns an accept bit to the command generation function. The command generation function then orders the station to transmit the command to the spacecraft. In the case where the command does not satisfy the bit-by-bit check or if the error code does not check, the command generation function stops the command process without sending the command to the spacecraft and the operator is asked for instructions. Should repeated retransmission of the command prove unsuccessful, the operator must enter a backup mode of commanding, either via the NDPF ADPE or by ordinary communications to the remote station to transmit the commands that were prestored at the station. After the command generation function has determined that a command or command block has been properly received at a remote station, transmitted and echo checked, it passes control to the command message update function.

It is the task of the command message update function to determine that the spacecraft has properly acted upon the transmitted command. The command message update function maintains a continuous record of the last mainframe received. When it gains control after a command has been sent, it updates that record. Thereafter, each time it gains control, it searches the working buffer of changed and updated telemetry parameters. From this telemetry, the command message update function determines the spacecraft response to the command. The command message update function checks to insure that the proper vehicle function was executed in response to that command and also that no other vehicle function was executed. The operator is kept informed of the command status via his display. Control is then passed to PCM telemetry processing function and the processing cycles is reinitiated.

The process in which software execution takes places during real-time commanding is cyclic. There are two considerations of importance during this process:

- The operator is in control at all times and commands are never sent except on his specific approval
- The cyclic execution process must take place within the time it takes to receive one telemetry mainframe, otherwise data will be lost and operations cannot be maintained. Times estimates of this critical cycle will be continually updated during the software development period and actual timing data will be acquired as soon as possible during that period and thereafter.

Another commanding process that takes place in real-time is the translocation of a block of commands destined for the stored command programmer for later execution. Once again the operator enables command transmission and the command generation function checks to insure that the remote station received the commands properly. When that check is complete, the commands are sent to the spacecraft and the spacecraft retransmits the contents of the stored command programmer to the OCC. When the command message update function gains control, it checks the stored command programmer memory contents bit-by-bit with the commands that were sent by the OCC and informs the operator of

the status determined. Only when the operator is satisfied that the commands are stored in the stored command programmer properly does he allow them to be executed. He does this by the transmission of a real-time command that changes the status of the stored command programmer from standby to process. The commands stored in the stored command programmer are then automatically executed according to the stored time of execution.

The execution of stored command programmer commands, in view of a station with accompanying telemetry transmission, is checked by the command message update function in the same way that real-time commands are checked. A command list is maintained by the command generation function that is identical to that in the stored command programmer, except that the stored command programmer commands contain vehicle time of execution appended while the command list has the equivalent GMT. Thus, at the appointed execution time, the command message update function begins to look for telemetry verifying the command execution. The operator is kept informed via his display of this command execution status. He may, at any time, stop the command by transmitting a real-time command to change the status of the stored command programmer from process to standby thereby inhibiting further command execution.

Only one further aspect of the real-time software execution process remains, the status of commands that were executed by the stored command programmer while out of sight of a station. This command execution data is stored on the narrowband tape recorder and is telemetered to the ground during a real-time pass. The process described below is implemented in the OCC software design. Whenever a command load destined for the stored command programmer is generated in non-real-time the command message update function is called to predict the vehicle status to the end of that command list execution so that the proper vehicle status is known in advance at the beginning of every pass. When real-time operations begin, the command message update function is called to compare this predicted status with the actual vehicle status being

transmitted via telemetry. If the functions agree, it is assumed that the vehicle is operating properly and the operator is notified. If the functions do not agree, the operator is informed which vehicle functions have failed or are malfunctioning and he then decides what action is necessary.

The basic concept incorporated in the design of the OCC software is that the operator is in control and is called upon to make all meaningful decisions necessary for the software during mission operations. The computer, including its software, is a tool that is used in carrying out the operator's decisions. At every step of the software operations, the operator is in the loop and is in control. He is kept informed of the status of all operations via the display terminals and he controls these operations via the control devices provided. This operator control applies to both real-time and non-real-time operations.

6.3 NDPF SOFTWARE

The NDPF configuration includes those software functions involving digital processing of imagery as well as PCM and DCS information. It produces both bulk and precision images using the computer and photo-optical equipment.

Additional functions necessary to support a complex system of image production and dissemination are also provided. These functions include processing quality control, production control, system scheduling, accounting, and data storage and retrieval, as well as user liaison (e.g., receiving requests and shipping products).

6.3.1 Information Management

Information management not only in the data services laboratory but in the entire NDPF is performed by the information management program.

The information management program functions under the control of the computer operating system. It is designed to allow nonprogrammers to specify data structures, using an English-like language, and to write retrieval programs that include Boolean operators. The program also performs diagnostics and communicates with the user in meaningful terms. All NDPF files are managed by the information management program

except for the master digital data file which is maintained and updated as part of the PCM processing function. To provide these capabilities the information management program consists of a series of processing components designed to support a significant range of data structure. These components are the file creation, file revision, file maintenance, retrieval and sort, output, and remote terminal operation.

File creation allows the user to define the data that makes up his file using a direct and free-format language. It also provides the capability to specify certain automatic functions, such as data conversion and editing, that are to be performed.

File revision provides the user the capability to reformat data fields presently stored in a file. Using this component, field data may be changed, deleted, added to, or relocated.

File maintenance allows the user to add, delete, or modify records or subrecords of a data file. All processing is done by logic statements written by the user in English-like language. All input and output functions are automatic and auxiliary output files can be created along with the maintenance process.

Retrieval and sort allows the user to retrieve desired data by specifying retrieval conditions. Comparison operators, negative operators, Boolean connectors, and geographic retrieval operators are also provided. Sort capabilities allow the user to specify the manner in which he wants his data sequenced.

Output (information management program report generator) provides the user with the capability to format his reports and perform summarization totaling and subtotaling. It also provides the capability to specify whether output is print, tape, card, or any combination of these forms.

Remote terminal operation allows the information management program to interface with terminal devices. It provides the capability to initiate tasks from the terminals to do file updating, data retrieval, and data display.

Utility support provides the user with a collection of utility programs for specialized processing applications, such as converting a file for use with the information management program.

The files specified for the NDPF are controlled by the information management program. File structure, generation, maintenance, retrieval, and output is done through the information management program to satisfy NDPF and user requirements. Consequently all requirements for computer services are a function of file use, job type, and information management program requirements.

The following additional files have been identified as being necessary to satisfy the information storage and retrieval requirements of the NDPF:

1) The index/abstract file provides an index to all RBV, MSS, and RBV calibration imagery processed and stored within the NDPF. This includes all corrected, precision processed, and color composite images generated in the NDPF. All content data regarding the imaged area developed within the NDPF and supplied by the users is contained in this file.

2) The DCS file provides a history of ground sensor data transmitted from the data collection platforms. Sensor data is changed into engineering units and is time annotated. The file is maintained on tape. DCS data is provided to users in digital, card, or listing form. Data content can be all sensor data or any requested subset of the total data.

3) The master digital data file provides a history of all the time-corrected PCM housekeeping telemetry. This file also contains the time corresponding orbital and attitude parameters necessary for data analysis on the health of the ERTS spacecraft and its sensors. As previously indicated, this file is maintained and updated in the PCM processing phase. Copies and/or printouts are provided upon user request.

4) The time history file provides a history of previously verified and corrected GMT. This data is used to keep the time continuity of the PCM telemetry throughout the lifetime of each satellite. This file also provides the only means of correctly time annotating the playback data if received separately from the real-time data. The time history file is used in the preprocessing phase of the PCM processing.

5) The DCP file identifies data platform locations and the calibrations required on each sensor. It is an internal system file and is accessed only by the DCS data base generator program.

6) The library index file provides a record and the location of.all physical items stored in the active and archive library of the NDPF. A brief summary of the data types maintained in this library is in Table 6-1.

7) The production control status file contains the current status and summary information on all jobs and work requests in the NDPF. This file is updated daily with transactions from the various processes that are monitored. Summary reports on various activities are provided according to specified requirements.

6.3.2 PCM and DCS Data Processing

The telemetry data from the active pass are forwarded from the OCC in the form of a magnetic tape in a machine readable form. This tape is further processed to produce a master digital data tape and to obtain the image annotation information. Data from the data collection system are received from the OCC and quality verified prior to structuring for storage and retrieval. The applications of software involved is as described in the following paragraphs.

The PCM and DCS data base generator function corrects the GMT assigned to the PCM telemetry handed over by the OCC, builds a history of the observatory clock/GMT relationship and generates a schedule for the optimal processing of the digitized PCM tape. The best fit ephemeris is obtained to build a file of corrected PCM telemetry time data and orbital parameters.

For the DCS telemetry, the PCM and DCS data base generation function does the entire job of checking, editing, and quality determination, since the OCC processes DCS data only to the point of decommutating, gross quality checking and frame synchronizing.

With the preprocessing portion of the PCM and DCS data base generation function completed, the precise error resolution function is called (if DCS data is not being processed). The precise error resolution

Table 6-1. Library Storage

	Active	Archive
Image		
RBV video tapes	3 mo	Destroy
MSS tapes (PCM)	3 mo	Destroy
Digital tape	1 yr	Destroy
Film masters	1 to 5 yr	200 yr
High density archival - tape		
RBV	1 yr	20 yr
MSS	1 yr	30 yr
High density archival - photo/digital	1 yr	200 yr
Information Storage		
Observatory Data (master digital, DCS, ephemeris, etc.)	1 to 5 yr	30 yr
Management Files		
Index/abstract	5 yr	At least 30 yr
Library index, Production control	Indefinite	Not applicable
Hard-Copy		
Montage catalog	5 yr	200 yr
Abstract catalog	5 yr	Destroy
Maps	Indefinite	Purge

function has two modes: the initial attitude determination mode in preparation for bulk processing and the precise attitude determination mode in preparation for precision processing.

Observatory attitude and attitude rates are estimated by using a weighted least squares estimator to process ground truth, horizon scanner, reaction wheels, yaw gyro, and solar panel data. The data is first statistically edited by data set before being smoothed with a second degree polynomial. The accuracy of the estimation is increased by using the dynamic equations of motion which contain all factors affecting the observatory attitude, the more important of which (such as solar and magnetic torques) must be accounted for. In either the precision or bulk processing modes sun angle, subsatellite point, frame center, frame corner coordinates, and locations of even degree and half degrees (by interpolation) on imagery are computed.

The PCM and DCS data base generation function is now called to generage the annotation tape for each image. The annotation text consists of the following.

1) Geographic tick marks
2) Registration fiducials
3) Sensitometric strips
4) Identification number
5) Picture time to the nearest 0.01 second
6) Subsatellite point in geographic coordinates
7) Spacecraft attitude
8) Sun angle
9) Receiving station
10) Orbit number
11) Picture center in geographic coordinates
12) Heading

13) UTM designation of picture center

14) Deviation of UTM grid from meridians

15) DCS data available for the image area

16) Satellite designation

17) Data of processing

18) Cloud cover in tenths by quadrants

19) A group reserved for coded remarks.

All except items 2), 3) and possibly 19) require either software processing or software storage and retrieval, and it is at this point in the processing that a technique for making all this information available to either the precision or bulk processed imagery is established.

In the bulk processing mode, the master digital data file is prepared by merging the digitized PCM data tape, the GMT, orbital parameters, attitude data, and DCS data.

If the data being processed are DCS, the PCM and DCS data base generator skips PCM related routines and the precise error resolution function to generate the DCS data base by verifying and checking values, separating data by platform, and attaching GMT. A DCS output tape is prepared.

6.3.3 Image Processing

The next set of applications software used is applied to the imagery for either bulk or precision processing and is called the digital image processing function. Bulk processing is on a daily basis, with the principal product being annotated black and white images on photographic film masters. Precision processing is provided only on request. A description of the various modes of image processing along with the corresponding software applications programs is shown in Table 6-2. The digital image processing function uses a high degree of parallel processing for efficiency. For example, the processes of reading an image from high density tape, storing it in direct access storage, and detecting reseau may all be performed concurrently.

Table 6-2. Operational Modes of RBV and MSS Sensor Data Image Processing

Description	Mode	Software Applied	Routine
	Bulk Mode 1		
No geometric correction		(Note All hardware functions except for computation of shading and gain correction based on RBV calibration images)	
Shading and gain correction		Calibration	
MSS correction for earth's rotation effects		Read data cards to determine processing options	BDIPC
		Read bulk mode images from RBV data buffer	BRIFCU
		Write image onto direct access storage device	BWIDAS
		Read image from direct access storage	BRIDAS
		Compute and apply photometric calibration and gamma correction to RBV and process control programs	BCRCT
	Bulk Mode 2		
Geometric correction of RBV		Read data cards to determine processing options	BDIPC
Correction of MSS under computer instructions		Read high density tape, annotation data, etc.	BRIFT
		Locate and measure reseau points and PPR process control programs	BDR
Shading and gain correction			
	Precision Mode I		
Geometric correction of RBV		Read data cards to determine processing options	BDIPC
Correction of MSS through use of attitude, ephemeris, and ground truth data		Read high density tape, annotation data, etc.	BRIFT
		Write image onto direct access storage device	BWIDAS
		Search attitude and ephemeris history tapes	BSAET
		Locate and measure reseau points	BDR
Image transformation into UTM or oblique mercator coordinator		Read image from direct access storage	BRIDAS
		Apply proper RBV output to input image mapping	BCROIM
		Apply proper MSS output to input image mapping	BCMOIM
Shading and gain correction		Apply geometric point correction	BGEOM
		Write the image with annotation on high density tape	BWHOT
		Write 1600 BPI tape	BWLOT
Nonstandard composite color balance (no relationship with computer, performed on color printer)			
	Precision Mode II		
All of Precision Mode 1 corrections		Read data cards to determine processing options	BDIPC
One or more of the following:		Read high density tape, annotation data, etc	BRIFT
		Write image onto direct access storage device	BWIDAS
• Image motion compensation		Search attitude and ephemeris history tapes	BSAET
		Locate and measure reseau points	BDR
• Image transformation into specified grids		Read image from direct access storage	BRIDAS
		Generate structured noise correction table	BCSN
• Image enhancement		Apply structured noise correction to each line of image	BRSN
		Apply single point radiometric correction to RBV images	BRSRC
• MTF correction		Apply MSS calibration data to smooth values Apply gain and gamma correction for atmospheric scattering.	BMSRC
• Structured noise removal		Remove reseau by interpolation	BRR
• Reseau removal with cosmetic fill-in		Apply blemish correction table	BRB
		Apply proper RBV output to input image mapping	BCROIM
• Radiometric adjustment for atmospheric effects		Apply proper MSS output to input image mapping	BCMOIM
		Apply geometric point correction	BGEOM
		Apply multipoint radiometric correction	BAMPC
		Write the image with annotation on high density tape	BWHOT
		Write 1600 BPI tape	BWLOT
• RBV blemish removal		Apply blemish correction table	BRB

Processing for any image begins with the reading of control cards. These identify the image of interest, provide the information necessary to permit the extraction of required data from other files, such as the attitude/ephemeris time history tape, specify the operation to be applied to the image, and supply any processing parameters which are under the control of the user.

The image to be processed is either read from high density tape or loaded directly from the RBV bulk line control unit and may be stored in direct access storage. If a geometric correction is required particularly when processing MSS imagery, spacecraft attitude and altitude data is needed and the appropriate tape is searched.

Reseau detection is performed for all RBV imagery in the computer.

Image data which has been stored in direct access storage is read into memory for processing. The process of moving image data in and out of direct access storage occurs at several places in the flow.

Structured noise is characterized and removed if desired. Since several images are required for noise characterization, it is possible that characterization but not removal will be requested. Note that these operations are a precision mode II option.

Single-point photometric corrections are applied to RBV or MSS images if desired. These corrections adjust for shading and gain errors as well as perform precision mode II options including atmospheric scattering compensation, gamma correction, and application of simple image enhancement procedures such as thresholding and video stretching. If RBV multi-point radiometric corrections are to be applied, the single-point correction is deferred and applied later as a combined operation.

Reseau removal and blemish removal are performed if requested. If a geometric correction is requested together with an appropriate mapping function, the correction is applied through either point shift or interpolation techniques. The correction may include transformation into any one of a number of preprogrammed coordinate projections.

Multi-point radiometric corrections are applied if desired. These may include IMC and MTF corrections as well as selections from a list of image enhancement techniques which can be implemented through use of a multi-point space domain operator of moderate size.

Provision is made for outputting images, annotation and shading correction data on high density and/or 1600, 800 or 556 bpi tapes as required.

The digital image processing function provides the capability of supporting simple calibration image processing (bulk mode 1) to implementing the complete list of options for precision mode 2.

In conjunction with the digital image processing function, a software support function is needed to drive and control certain hardware for satisfying the image processing requirements. This software support is called the image processing support function and has two distinct operations: external equipment control and image generation control.

The external equipment control provides top-level control to the RBV and MSS bulk processing. It interfaces the RBV and MSS bulk line control units to provide control to the RBV and MSS reproducers and high density tapes.

The image generation control provides control for the precision photo restitutor when operating in the computer-controlled mode. The computer-controlled mode drives the precision photo restitutor to prepare a corrected RBV or MSS image based upon reseau and attitude information. The film is then developed for archiving and to meet user requests.

The computer-controlled mode provides corrections based upon the improved spacecraft attitude and position for MSS images, and defines corrections based upon reseau positions, to drive the four computed incremental values (x-position, y-position, zoom, rotation) required by the precision photo restitutor.

It should be noted that the imagery and related information are transferred to the archives. The software function to perform the data handling for generation and maintenance of archival files is the information management function. The information management function also processes user inputs into the archival files.

6.4 SOFTWARE ORGANIZATION AND CAPSULE DESCRIPTIONS

The OCC software is organized into five functions and the NDPF software into five functions, where a function is a group of computer programs working together to perform a major task (Figure 6-1). Each function is subdivided into modules where a module consists of a single

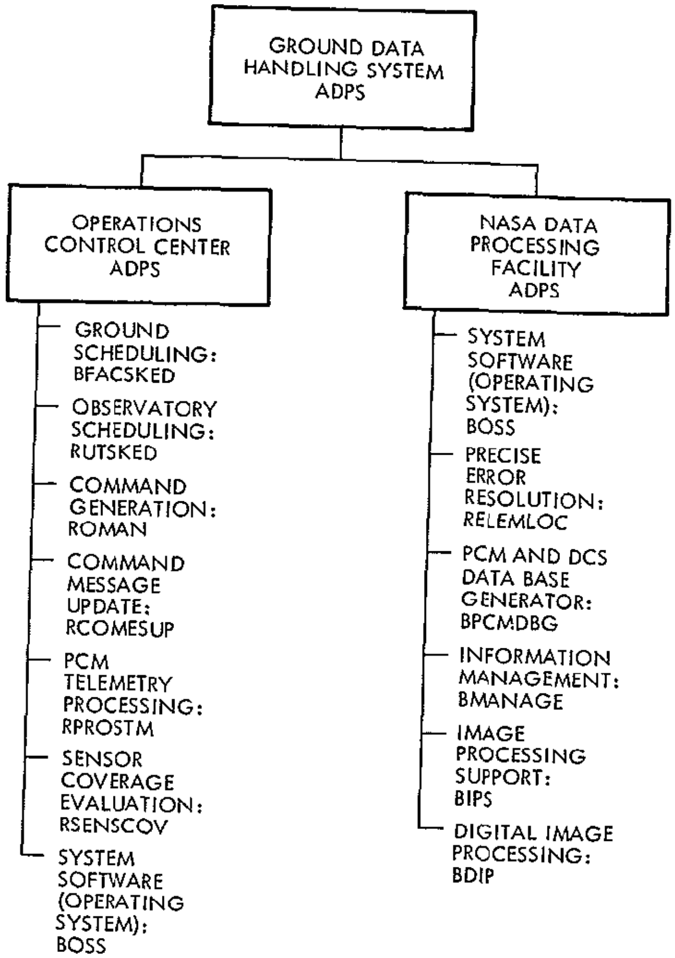


Figure 6-1

TOP-LEVEL SOFTWARE structural tree

computer program. Each module is subdivided into routines. A routine is the smallest collection of serial codes which has recognizable input and output, and performs one or more tasks. Figure 6-2 shows a graphic representation of the software structure to the module level. Each software element operates under computer control by the BOSS operating system executive and under manual control by the operator.

A brief description of each element, from function to routine, is provided in the following sections to describe the design. The appendix to this volume contains a Milestone B description of each element

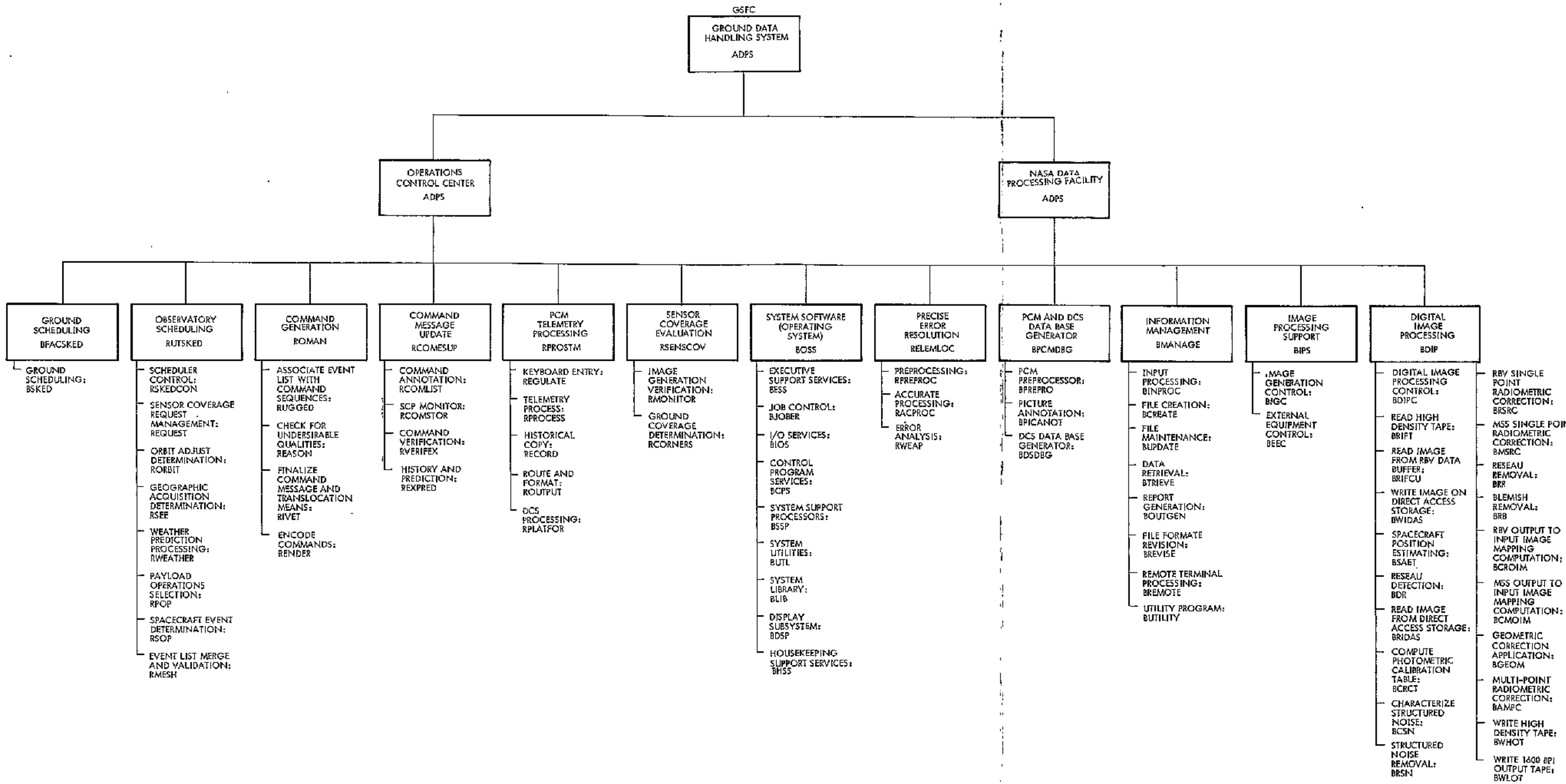


Figure 6-2

GDHS TO MODULE LEVEL SOFTWARE structural tree

required by the design. Also described are the special-purpose software requirements, which include:

- A test pattern generator for testing the ADPE display system interface
- Data interface buffer echo check test software to test the ADPE/data interface buffer interface
- Software to test the ADPE/PCM decommutator interface. Accepts simulated telemetry and displays data on the display system.
- Software to test the GMT timing data input to the ADPE.

No Milestone B specifications are included in the appendix for the above applications software routines.

6.4.1 OCC Software

6.4.1.1 Ground Scheduling Function - BFACSKED

From the desired user experiments, station commitments and capabilities, and spacecraft ephemerides and capabilities, this function determines the required station support, mission schedule reports and a history of ERTS scheduled events.

6.4.1.2 Observatory Scheduling Function - RUTSKED

From a consideration of the requests for sensor coverage, weather predictions, spacecraft ephemeris and other input data, this function produces a conflict free event list of spacecraft, sensor and ground support activities.

Input Processor - READIN. Reads in all data for the RUTSKED function and stores it in working files for usage by the following routines.

Sensor Coverage Request Management Module - REQUEST. This module accepts user requests for sensor coverage and outputs unambiguous bounded geographic area cells to be photographed.

- User Request File Maintenance Routine - REKFILE. Accepts the sensor requests and builds and maintains a file that represents the aggregation of all future required coverage in cells of 30 x 30 nautical miles.

- User Request File Report Generation Routine - REKCHECK. Generates reports on the state of satisfaction of individual user requests or reports on the status of the entire sensor coverage request file.

- Geographic Acquisition Determination Module - RSEE. Based on the areas representing sensor coverage requests together with the spacecraft ephemeris and predicted station contacts, a list of sensor acquisition opportunities is determined.

- Ephemeris File Maintenance Routine - REPHEMER. Maintains the file of ephemeris data by accepting new ephemeris data as it becomes available and integrating it into the existing file.

- Ephemeris Interpolation Routine - RPOLATE. Interpolates between the given spacecraft state vectors using a technique known as Hermitian Interpolation to yield an accurate determination of spacecraft position at any desired time.

- Acquisition Table Generator Routine - RAKTABLE. Builds and maintains the table of all possible geographic area acquisitions based on the latest spacecraft predicted ephemeris. Also generates the predicted weather request message.

- Payload Operations Selection Module - RPOP. This module schedules the actual sensor coverage to be implemented from the previously processed acquisition list considering such factors as request priority, predicted weather, and manual input.

- Value Assignment Routine - RVALUES. Assigns a quantitative value to each acquisition opportunity based on priority and weather.

- Payload Operations Selection Routine - RCHUZPOP. Schedules and outputs the actual sensor and video tape recorder events to be implemented from a consideration of the sensor acquisition list and recorder status noting those possible sensor events that conflict for operator resolution.

- Manual Modification Routine - RMOD. Any conflict resolution or event list modification is performed via RMOD with operator input data.

6.4.1.3 Command Generation Function - ROMAN

This function accepts the previously generated event list and transforms it into the required encoded command load ready to transmit to the spacecraft. It provides sufficient operator interation to control the

command generation process. The real-time portion of this function communicates with the ground station to effect real-time commanding.

Associated Event List with Command Sequences Module - RUGGED. This module transforms the event list to an initially selected command list by associating events with previously generated analogous command sequences. It also accepts manually input commands.

- Input Routine - RNPUT. Reads and stores the input data for the module

- Event/Command Matching Röutine - RCOMSEQ. Associates command sequences with events based on prestored command sequences. Manually input commands are accepted as well.

- Execution Time Computation Routine - RTIME. The commands are assigned to blocks (groups) for transmission. Execution times for all real-time and stored program commands and blocks are assigned. The execution times are maintained on both a GMT and spacecraft clock basis to allow effective operator interaction.

Command Checking Module - REASON. This module checks the command list for constraints violations.

- Error Checking Routine - RCHECK. Checks each command in the list against a command constraints matrix to ensure that there are no errors in the list.

- Load Order Routine - REORDER. Reorders the command list from one of chronological order to one of interrupt safe ordering in the event command transmission is interrupted.

Command Formatting Module - RENDER. Formats the commands into the proper bit structure compatible with the observatory command system.

- Command Formatting Routine - RCTAB. Converts each command in the list to a bit pattern for transmission to the observatory. Manual modifications may be made before the commands are stored for later real-time translocation.

- Command Display/Check Routine - RCDISP. Displays each formatted command in a form for review by the operator. The commands are converted from the bit structure to the literal description and command number to ensure that the bit structure indeed represents the requested commands.

7

Real Time Commanding Module - RELAY. This module causes commands to be sent to the ground station under operator control, validates that these commands were received properly at the station, signals the ground station to transmit the command to the observatory, and determines if the echo chock was proper.

- Command Translocation Routine - RSEND. Formats and encodes the commands for translocation to the ground station and sends them via the NASCOM communications link.
- Command Validation Routine - RECEIVE. Determines the command translocation status the message received from the ground station.
- Command Echo Check Routine - RECHO. Determines at the OCC if the command transmitted from the ground station echo checked properly by means of a message from the station.

6.4.1.4 Command Message Update Function - RCOMESUP

This function provides a verified, up to date image of the stored command programmer and real-time command status; predicts future command status and allows monitoring of anomalous command behavior. Command verification is based on spacecraft telemetry.

Command Verification Module - RVERIFEX. This module annotates the command schedule during non-real time operations, and during real time or post pass checks the telemetry to determine if command have executed properly.

- Command Schedule Annotation Routine - RANOCOM. Provides the daily command schedule annotated with text material indicating the command identification and the verification to be expected after command execution.
- Command Verification Routine - RCOMCOMP. Performs command execution verification automatically utilizing the PCM narrowband telemetry data as processed by the PCM processing function, RPROSTM.
- Command Status Display and Control Routine - RCOMDIS. Provides control and display for the RCOMESUP function.

Stored Command Memory Comparison Module - RCOMSTOR. This module checks for proper command storage in the SCP and displays the comparison data.

- Memory Comparison Routine - RSTOCHECK. Compares the stored contents of the observatory command memory with the expected.

- Stored Command Memory Display Routine - RESTORIND. Displays the entire memory image. Each command stored in the command memory is given.

Command History and Prediction Module - REXPRED. This module generates a history of executed commands and predicts the observatory state at a given time (input).

- Command History Routine - RHISTORY. Maintains the executed command history.

- Observatory Status Prediction Routine - RPREDICT. Generates a predicted observatory state in an input time based on current status and expected command execution.

6.4.1.5 PCM Telemetry Processing Function - PROSTM

This function provides the capability to process observatory telemetry data in real time and playback recorded data in non-real time. Changed values are extracted, limit-checked, converted to engineering units, and displayed. A trend file is maintained for analysis of slowly varying parameters. Also DCS data is recorded for processing by the NDPF.

Real Time Control Module - RATPAC. This module controls the execution of all real-time software. This includes the real time portions of the command generation function and the command message update function as well as the PCM processing function.

- Main Controlling Routine - RMAIN. Selects which program is to execute and allocates time for the execution.

- Prepass Setup Routine - RPREPASS. Initializes the data base prior to a station pass.

- Program Scheduling Routine - RSKED. Activates routines in the active list, selects the next routine to execute and transfers control to this routine.

- Interval Timing Routine - RTIMER. Manages the time allocation to the routines to be executed.

- Input/Output Processor - RID. Provides services for interrupts and input/output processing during real time operations.

PCM Input Processing Module - RINPUT. This module reads in the data from the PCM/DHE, selects changed values, performs limit checks and stores data for ROUTPUT.

Engineering Conversion Module - RPROCESS. This module converts selected observatory parameters from telemetry units to engineering units and stored for display by ROUTPUT.

Telemetry Data Recording Module - RECORD. This module builds a record of the converted telemetry data, grouped by subsystem. Magnetic tape data is generated for each main frame, and a hardcopy printout is output. Trend data may be recorded on option using parameters selected by the operator.

- DCS Processing Routine - RPLATFOR. Is used during non-real-time to transfer the DCS data from the hardware to magnetic tape for later processing by the NDPF.

PCM Output Processing Module - ROUTPUT. This module generates the trend display, displays PCM data and displays error messages.

- Trend Display Routine - RTRNDISP. Displays short term trend data on a limited number of selected parameters.

- PCM Data Display Routine - REQFORM. Formats the PCM display data for output onto the CRT by the system display software.

- Input Processing Routine - READATA. Reads all data for the SENSCOV function into core.

- Shutter Time Calculation Routine - RSHUT. Determines the RBV shutter times based on the executed command history and payload model.

Frame Location Module - RCORNERS. This model calculates the geopositions of the nominal frame center and corner coordinates of each frame commanded by the executed command history. This data is used by RUTSKED to update the sensor coverage request file, and to provide the NDPF with nominal frame data.

6.4.1.6 Sensor Coverage Evaluation Function - RSENSCOV

This function determines the sensor coverage that has taken place by compiling the list of calculated sensor shutter events and by the determination of the ground locations of the frame corners. The nominal observatory attitude is used in this determination.

Image Generation Verification Module - RMONITOR. This module produces the shutter events list in order to determine the video sensor coverage.

6.4.2 NDPF Software

6.4.2.1 Attitude Determination Function - RELEMLOC

This function determines the bulk process estimate or precision estimate attitude of the spacecraft in order to obtain precise location of retrieved images by removing image geometric error. Spacecraft three-axis attitude and attitude rates are determined from measurements pitch, roll, yaw angle errors; momentum wheel rates; solar panel position; spacecraft on sun ephemeris; and ground truth data. The equations used include all of the important effects on attitude determination.

Preprocessing Module - RPREPROC. This module assembles all the data required for attitude determination, smooths the data and converts to observations based on the horizon profile and attitude reference system. Spacecraft and solar positions are determined by interpolating from received ephemeris data.

- Data Input Routine - READERR. Input data is read from the PCM data tape to input data on horizon scanners, rate gyro, reaction wheel, etc. Ground truth data is read from cards when available.

- Ephemeris Data Interpolation Routine - RORBIT. Solar and spacecraft position data is computed at intermediate points between those provided in the ephemerides.

- Data Editing Routine - RDAPROC. Data are edited and smoothed by using a second degree polynomial fit after obviously bad data is removed. Scanner and gyro data are converted to observations.

- Oblateness Correction Routine - ROBLATE. Removes spurious readings of pitch and roll by the horizon scanners which arise because of the oblateness of the earth.

Accurate Processing Module - RACPROC. The equations of motion are integrated, the matrix of partials is generated, and the vehicle attitude state vector is estimated based on the observation data. The orbit and attitude annotation information is output.

- Parameter Calculation Routine - RINPAR. Spacecraft equations of motion are integrated and numerically generates the partial derivatives. The Runge-Kutta method is used for the integration.

- Data Filter Routine - RFILTER. Smooth observations are processed by a weighted least-squares estimator to obtain image center and corner coordinate estimates.

- Image Annotation Routine - RIGRATE. Sun angle, satellite subpoint, frame center and frame corner coordinates are assembled for annotation of the video images.

Error Analysis Module - REWEAP. This module controls a set of routines which improve on telemetry data attitude determination by incorporating ground truth data and yaw estimates from precision photo restitutor correlation. The combination of these data gives the precision attitude determination estimate.

- Time Sort Routine - RSORT. Accepts as input the observed ground truth coordinates with accompanying run and vehicle time of acquisition. Routine RSORT then converts vehicle time to GMT, time orders the acquisitions, and checks for obvious input errors. It also retrieves the historical or recorded coordinates of the ground truth from the data base for subsequent use by Routine RGOTCA.

- Ground Truth Determination Routine - RGOTCA. Calculates the predicted image plane coordinates of the ground truth, utilizing the most current information concerning vehicle position and attitude. This routine also forms the difference between the observed and calculated coordinates.

- Partial Derivative Calculation Routine - RPART. Calculates the various partial derivatives of the image plane coordinates with respect to the independent variables. RPART also forms certain combinations of these derivatives for use in the routine RLEASE.

- Partial Derivative Inversion Routine - RLEASE. Inverts the matrix of partial derivatives formed by RPART. After inversion a simple matrix multiplication produces the variables necessary to perform the update.

- Output Routine - ROPE. Outputs all data and terminates use of the module RWEAP.

- Nodal Crossing Calculator - RENODE. Calculates the nodal crossing time and nodal vehicle position for a particular revolution of interest.

- Yaw Estimate Routine - RYAW. Uses output data from the precision photo restitutor correlator to give an estimate of spacecrafy yaw.

- Precision Attitude Estimate Routine - RCOMSEST. Combines the bulk rate attitude estimate with ground truth data and precision photo restitutor correlator yaw estimates, to give the precision spacecraft attitude estimate as well as the precise image corner calculations.

6.4.2.1 PCM and DCS Data Base Generator Function - BPCMDBG

This function generates the PCM telemetry data base containing the calibrating housekeeping, corrected GMT, orbital and attitude data. This data base is maintained on a master digital data tape. In addition, the video image annotation data are created.

PCM Preprocessor Module - BPREPRO. This module edits DCS telemetry, corrects the GMT in the PCM telemetry, creates a PCM digital tape schedule to allow efficient processing, generates the spacecraft reference file of corrected GMT and orbital parameters.

- PCM Time Correction Routine - BTIMCOR. Identifies and corrects discrepancies in the GMT assigned to the PCM telemetry data. A history of spacecraft clock/GMT relationship is maintained for interpolation/extrapolation of ground times. Propagation delays are accounted for.

- Close-out Preprocessor Routine - BWRAPUP. Time history file is updated to include the spacecraft clock/ GMT relationship for the data processed in the current computer run. The digitized PCM tape contents are scanned and a PCM digital tape schedule is generated to allow the tapes to be processed in an optimal sequence.

- Reference File Generator Routine - BREFFILE. Generates the spacecraft reference file which contains the corrected GMT and orbital parameter data.

- Merge Orbital Parameters Routine - BMERGORB. Orbital parameters are merged with the PCM telemetry time data. The orbital parameters are adjusted to each corrected time point.

Picture Annotation Module - BPICANOT. From the spacecraft reference file and the attitude history file, this module computes and summarizes all the parameters required for video image annotation for bulk processing and writes an annotation tape.

- Annotation Generation Routine - BANNOTE. Generates the annotation tape showing even and half degree marks and a summary report containing the latitude/longitude of the frame center and corners.

- PCM Data Tape Read Routine - BREADPCM. Inputs the digitized PCM data tape previously generated and outputs onto the master digital data file.

- Data Merge Routine - BMERGEREF. Merges the GMT, orbital parameters and attitude data from the reference tape with the spacecraft performance data and outputs onto the master digital file.

- Redundant Data Strip Routine - BRITEMDD. Checks for overlapped or redundant data as the PCM tapes are being processed. If overlap is not detected, DCS data are merged with performance data and the merged data are written on the master digital data file. If redundant data are detected, the data of lower quality are eliminated and the resulting data are written on the master digital data file.

- Run Summary Routine - BSUMMARY. Assembles and prints a run summary, lists the tapes processed, summarizes coverage, and reports out of limits data. The catalog of tapes stored is updated and optionally outputs performance data.

DCS Data Base Generator Module - BDSDBG. This module generates the DCS data base which contains the verified, identified, and calibrated DCS messages.

- Edit DCS Telemetry Routine - BDIGDCS. DCS telemetry on the tape that was prepared in the OCC is edited by checking for proper increments, flagging frame overlapping and a new DCS tape is prepared with the data from this pass added to that of previous passes properly identified. DCS data quality is determined and appended to the data.

- DCS Data Input Routine - BREADDCS. Reads the digitized DCS data tapes into core for processing, reads the DCS information file to identify the messages and outputs to the DCS data file.

- DCS Verification Routine - BVRFIDCS. Extracts, verifies, and identifies DCS messages to allow the sensor data to be categorized by platform. Output is to the DCS data file.

- DCS Data Check Routine - BEDITDCS. Each identified DCS message is checked for illegal sensor reading and illegal readings are flagged. Legal readings are calibrated.

- Time Error Removal Routine - BTIMEDCS. GMT tagged to the DCS data is checked for reasonableness and when found to be unreasonable, the GMT platform time data and tape accounting data are analyzed in order to assign a more correct time.

- DCS Data Format Routine - BRITEDCS. Formats and outputs the DCS data onto the DCS tape and optionally prints the required information.

6.4.2.3 Information Management Function - BMANAGE

This function creates and maintains NDPF data files to support the graphic displays and remote terminals. These files provide for effective retrieval of stored data.

Input Processing Module - BINPROC. This module screens, edits, converts and sorts the input data prior to file entry.

- Validity Checking Routine - BINEDIT. Input data are screened to confirm the validity of data. Input values are transformed by editing prior to storage.

- Data Input Sort Routine - BINSORT. Input data are ordered for sequential file creation and maintenance.

File Creation Module - BCREATE. File format and index specifications pertaining to data characteristics are determined to guide subsequent file operations.

- File Directory Creation Routine - BDENFILE. Data file format and index specifications are translated into a file format directory to guide subsequent file operations.

- Data Index Directory Creation Routine - BOENDEX. Data file format and index specifications are translated into a data index directory for subsequent file operations.

- Data File Creation Routine - BGENFILE. Data file is created based on the input data as directed by the file input specifications and file format directory.

- Data Index Creation Routine - BGENDEX. Data index is generated based upon the data file contents and the data index directory.

File Maintenance Module - BUPDATE. Input data are processed and merged with existing data file contents and associated data indexes are maintained to allow successful data retrieval.

- Data Editing Routine - BAUDIT. Data values in the edited input are compared against specified data file values to determine the acceptability of the data for file updating. Unacceptable data are optionally reported.

- File Update Routine - BUPFILE. File input specifications are translated into instructions to update the input data file. Updating is performed on the files according to these instructions.

- File Index Update Routine - BUPDEX. File indexes are updated in accordance with the storage of new or changed data to facilitate the retrieval of stored information.

Data Retrieval Module - BTRIEVE. An English-like language is provided to specify the data to be retrieved. Access to the proper data is gained by either direct search of the specified file or indirect search of associated indexes. Optionally, the output data are sorted.

- Data Retrieval Instruction Translation Routine - BREPILE. Input data retrieval specifications are translated into instructions for performing the data index and file search. Errors in the retrieval specifications are detected and reported.

- Data Search Routine - BREDEX. Data index fields in the retrieval instructions are examined and if the specified conditions are met for retrieval, the proper records are accessed and output for further processing.

- Data Examination Routine - BREFILE. Data are retrieved and the indicated records are converted as required and held for further processing.

- Data Sort Routine - BRESORT. Data records are sorted according to the input data retrieval sort specifications.

Report Generation Module - BOUTGEN. This module generates a report whose format and content are specified in a high-level language. Executable instructions are compiled from the input data report specifications that control and formulate the output in format, content, and media.

- Report Specification Translation Routine - BOUTPILE. Data report specification is translated into a set of machine executable instructions that perform the arithmetic and logical manipulations and produce the specified output.

- Instruction Execution Routine - BOUTFORM. Executes the previously compiled report instructions to perform the indicated manipulations. The data are summarized and converted to the specified form and content.

- Format Control Routine - BOUTCON. Output form and media is controlled by this routine. All formatting such as spacing and arrangement of output is accomplished here. Output records are routed to designated output devices.

File Format Revision Module - BREVISE. An existing data file is restructured and its format modified to permit the integration of additional data fields. Specifications for data field modification are accepted and the modified data file is produced.

- Format Comparison Routine - BREPARE. New format specifications are processed and compared with the current file format. Transformation instructions are generated to direct the file revision process.

- File Content Reformat Routine - BREFORM. Selected data are transferred from the current file and reformatted into the new format in accordance with the instructions for file transformations.

Remote Terminal Processing Module - BREMOTE. File updates, retrievals, and outputs via remote terminals and display units are processed. Communication between the terminal operator and the data files to be processed is established.

- Input Translation Routine - BRINPUT. Inputs from a remote terminal are translated into commands for entering data into a designated file. Errors that may occur are detected and displayed.

- Output Translation Routine - BEQUEST. Data requests from a remote terminal are translated into commands for retrieving and displaying data from a designated file. A high-level query language is provided for retrieval requests.

Utility Program Module - BUTILITY. Utility programs are provided which sustain generalized data file operations. Standard table generator and lookup routines are provided as well as retrieval and general output routines.

6.4.2.4 Image Processing Support Function - BIPS

Several pieces of special peripherals require computer control. The routines that manage these devices are contained in this function.

Image Generation Control Module - BIGC. This module acts as the controller for the generation of images on film. The two data streams of image and annotation data are merged to form annotated output images.

- Precision Photo Restitutor Real-Time Program Routine - BRPTP. Performs the translation, rotation, and scaling of the four incremental values (ΔX, ΔY, ΔZ, ΔK) referenced to the fudicial marks in precision photo restitutor coordinates.

- Precision Photo Restitutor Computer-Controlled Routine - BPOPC. Has a two-way communication with the precision photo restitutor commands, interrupts, film identification, fiducial coordinates necessary to interpret and control the precision photo restitutor. It transmits to the precision photo restitutor control commands, initial strip values, four incremental values/location. It calls the programs BPSP and BPRTP to generate the control image values. Annotation data are placed on the film via a cathode-ray tube.

External Equipment Control Module - BEEC. Several pieces of special equipment require computer control for correct operation. The

routines of this module select the proper device, provide control parameters, and control the flow of data to and from the equipment.

- RBV Data Buffer Routine - BRDBC. Provides top-level control to the RBV bulk processing. It will interface with the RBV bulk line control unit to provide control to the RBV reproducer and high density tape units. These items require commands to direct searching, reading, writing and provides timing control to keep them in sync. Therefore the program will keep track of timing and respond to interrupts. Calibration images will be read into the computer onto direct access storage. To generate shading information a section of the image will be processed at a time. The annotation, shading, and tick mark data will be formatted and transmitted to the data buffer.

- MSS Data Buffer Routine - BMDBC. Provides top-level control to the MSS bulk processing. It will interface with the MSS bulk line control unit to provide control to the MSS reproducer and high density tape units. The routine supplies to the hardware the information necessary to permit a data tape to be scanned and the information pertaining to the image of interest to be extracted and copied onto high density tape. Annotation is put on the high density tape as a header along with the time identification code. Control commands are sent to the MSS data buffer and interrupts are received and processed.

6.4.2.5 Digital Image Processing Function - BDIP

This function provides the method of correcting major errors in the ERTS imagery. The routines of this function correct sensor induced geometric distortions as well as attitude errors of the observatory. Output is on tape suitable for recording on the laser beam recorder.

Digital Image Processing Control Module - BDIPC. This module causes data cards to be read containing the processing options desired. On the basis of those options, the module calls on specialized routines to accomplish the desired processing.

Read High Density Tape Module - BRIFT. This program reads from the high density tape, annotation data, tick mark data, and image data. The image data are read using double buffers. This will allow reading into buffer 1 while the image writing program is writing buffer 2 onto direct access storage device.

Read Image from RBV Data Buffer Module - BRIFCU. This module reads an image from the RBV data buffer. It is the input/output

program that interfaces with the RBV data buffer control program (BRDBC) while reading RBV calibration images into the computer during bulk mode processing. Also the associate annotation data are input to the computer.

Write Image onto Direct Access Storage Module - BWIDAS. This routine is used which reading the image from high density tape into two buffers in core memory. The program writes the image onto a direct access storage device. While the first buffer is being filled from high density tape this program outputs from the second buffer onto a direct access storage device.

Spacecraft Position Estimating Module - BSAET. The attitude and ephemeris history tapes are searched for the data pertaining to the exposure time of interest. The spacecraft attitude, altitude, subpoint and sun angle records are extracted. An average ground height is selected from the terrain model to determine image scale.

Reseau Detection Module - BDR. The RBV data stream is searched to locate the reseau points and measure their location. If the points cannot be found, an error flag is set.

Read Image from Direct Access Storage Module - BRIDAS. This routine is used when sections of the image are read into memory for processing and for writing high density tape and 1600 BPI tape. Depending upon the area of the image to be read into memory the proper pointers and address are computed to control the input.

Compute Photometric Calibration Tables Module - BCRCT. This program computes the average intensity over each 25 x 32 element area of an input RBV calibration image and calculates the correction needed to adjust those averages to the nominal value, or it reads in a table of such correction values for a previously processed image. If a gamma correction table is desired, one is computed. Since this requires calibration images at several intensities, a message is printed out if insufficient data have been loaded in the computer.

Characterize Structured Noise Module - BCSN. This program adds input image data line-by-line (4096 sums). When a sufficient number of

lines (at least 1000) have been summed, the structured noise correction table is generated. If too few lines have been summed to permit structured noise characterization, a warning message is printed.

Structured Noise Removal Module - BRSN. This program reads in the structured noise correction table and applies the correction to each line of an input image.

RBV Single Point Radiometric Correction Module - BRSRC. This program applies a single-point radiometric correction (i. e., a correction dependent upon the input video at a single point rather than at several neighboring points) to RBV images. This type of correction can correct for shading, gamma, and atmospheric scattering (where the correction is a simple level shift) as well as perform video level adjustment operations such as thresholding and stretching. All corrections to be applied are combined in a single correction table which has entries for each 25 x 32 element area across the image. For each area, the correction table entries are used to compute a 64-entry table (based on 6-bit video quantization). The correction is then applied to each element in the area by a table lookup operation.

MSS Single Point Radiometric Correction Module - BMSRC. This program reads in the MSS calibration data and averages the values in several scans to obtained smoothed values. The smoothed data are then used to compute either a simple gain adjustment or a combined gain and gamma correction. As with the RBV, the corrections are altered to include atmospheric scattering compensation and video level adjustment if desired. The combined correction is a single 64-element table (based on 6-bit video quantization) which is applied to each pixel of the image by a table lookup operations.

Reseau Removal Module - BRR. For each reseau mark whose location is known, an image square containing the mark is read in. The pixels comprising the reseau mark are then replaced by video values computed by interpolation on the surrounding video data. Reseau marks whose locations are not known were nondetectable (i. e., not clearly visible) and hence do not require removal.

Blemish Removal Module - BRB. On the basis of observed reseau locations, this program computes a function which will map a scan-corrected image into the input image. A table of blemish corrections is read, and the mapping function is used to map these corrections into the input video.

RBV Output to Input Image Mapping Computation Module - BCROIM. A mapping which accounts for scan distortions, spacecraft attitude and altitude and desired output coordinate projection is required. Since the form of the mapping function is dependent upon the projection used, a selection of the projection desired (from a small list of preprogrammed candidates) is made. This selection causes the proper mapping and coefficient evaluation equations to be loaded. The required coefficients are then evaluated on the basis of reseau displacements, spacecraft attitude, and adjusted spacecraft altitude.

MSS Output to Input Image Mapping Computation Module - BCMOIM. A mapping which accounts for spacecraft attitude variations, spacecraft altitude, and desired output coordinate projection is required. Since the form of the mapping function is dependent upon the projection used, a selection of the projection desired (from a small list of preprogrammed candidates) is made. This selection causes the proper mapping and coefficient evaluation equations to be loaded. The required coefficients are then evaluated on the basis of the yaw angle and principal point time histories and the adjusted spacecraft altitude.

Geometric Correction Application Module - BGEOM. If point-shift (zero-order interpolation on the video) is to be used, the boundaries of the blocks of data which can be shifted are determined from the characteristics of the output to input mapping function. These data blocks are then shifted from the input to the output image through use of the move character instruction. If higher order interpolation on the video is to be used, anchor points in the output image are selected based on the characteristics of the mapping function. The anchor points are then mapped into the input image by the mapping function. Input image locations of intermediate output points are determined by linear interpolation between mapped anchor point locations. The video value assigned to a particular

output point is determined by interpolation over the video of the neighboring points in the input image.

Multi-Point Radiometric Correction Module - BAMPC. This program performs a multi-point radiometric correction on input images. The frequency characteristics of each correction to be applied are defined through a combination of parameter inputs and selection of preprogrammed expressions. The individual corrections are multiplied to from a composite frequency correction. The best mean squared error approximation of this combined correction by an N-point space domain operator is computed. (The value of N is dependent upon the amount of time which can be devoted to the processing of a single image. A probable value for N is 29.)

Write High Density Tape Module - BWHOT. Upon request this program reads annotation tape to get tick mark and annotation data. This information is written on the high density type as a header. The image data is then written on the tape.

Write 1600 BPI Output Tape Module - BWLOT. Upon request this program reads the annotation tape to get the tick mark and annotation data. This data is merged with the processed image data and written in a fixed format on the 1600 BRI tape. The processed image is read from direct access storage into two buffers ready for output to 1600 BPI tape.

6.4.3 System Software (Operating System) Function - BOSS

The operating system (BOSS) is designed to improve the performance of the data processing installation through efficient resource management. BOSS is capable of supporting real-time operations, decision-making, and spacecraft command/control. In addition, the system also provides general-purpose services required to support data processing needs. The system can operate in either a fully-automated environment where the majority of work is performed by or under the direction of automatic processing techniques, or in a partially-automated environment where manual intervention is necessary for many processing and control operations. The operating system consists of a comprehensive set of language translators, utility programs, and service routines

operating under the supervision and coordination of an integrated control program.

Executive Support Services Module - BESS. This module provides timely response to user requests and centralized control of the system's processing. BESS consists of a collection of main core-resident routines which facilitate high-level control flow routing. Composite services perform interrupt processing, executive administration, system initialization, and centralization of system data and information.

- Executive Interface Routine - BIEXEC. This routine assures uniform and efficient handling of the many basic system duties. BIEXEC consists of a collection of subroutines designed to make speedy decisions and to delegate control flow. Services such as multi-programming, main core storage management, interactive communication, program control linkages, timer services, program loading, error handling, and termination procedures are coordinated by this top-level administrator.

- System Information Reservoir Routine - BSIR. This routine simplifies the system's operation by making control information readily accessible to those routines relying on such information. Tables, control blocks, queues, and vectors constitute a portion of the information residing in BSIR. This information is necessary to describe the operating environment of the system and also to direct the flow of control within that environment.

- Initial Loader Routine - BXLOAD. Performs the task of placing the system in operation. At the command of the computer operator, BXLOAD loads the executive and job control modules into main core storage. These modules are then initialized, and they, in turn, conduct the final action necessary to achieve a complete system initialization.

- Interrupt Processor Routine - BIPROC. Centralizes interrupt handling to insure rapid analysis of the interrupt and prompt return of control to the interrupt program. BIPROC is a facility for processing both hardware-initiated and software-initiated interrupts. Such interruptions to the normal program execution flow may be caused, for hardware-initiated interrupts, by an input-output device, a timer, a CPU, or an external source. For software-initiated interrupts, these are the control program service interrupt and the illegal action interrupt. BIPROC determines the cause of each interrupt, stores the status of the interrupted program for subsequent return after interrupt processing and gives control to the appropriate interrupt analysis subroutine.

Job Control Module - BJOBER. This module supervises the overall operation of the job stream and insures the orderly flow of jobs through the system. BJOBER is responsible for controlling the progression of jobs through the system, and for assisting the individual jobs as they evolve from the starting phase through to the termination phase. Specifically, BJOBER exercises control in the areas of input job stream processing, work queue management, job initiation and termination, and job output retrieval.

- Job Input Reader Routine - BJIRDR. First of several operations required to place a job into execution and obtain its output. BJIRDR is a facility to accomplish the task of reading the input job stream. Under this primary task fall the subtasks of decoding the job control statements, generating job control tables and queuing the job's data as subsequent input to the BJSTST routine. Since input job stream reading is a time-consuming activity, this task is interleaved with other job processing to yield a more productive operation.

- Job Starter/Stopper Routine - BJSTST. Performs duties necessary to place a job into execution, and thereafter directs the duties required at job termination. At job's start, the job is dequeued, its system resources are allocated, and its software is initially loaded into main storage. At job's end, its system resources are de-allocated, its output files are queued, and other termination duties are performed. As job starting and stopping are apt to be resource or input-output bound, the BJSTST routine can be interleaved with the processing of other system jobs.

- Job Output Writer Routine - BJOUTW. Provides a facility to write the job's output information as directed by the job submitter. The job's output, as scheduled by the BJSTST routine, is first dequeued and then it is written to the appropriate peripheral output device. BJOUTW input-output processing is interleaved with other system processing to maximize resource utilization.

Input-Output Services Module - BIOS. This module provides the system with a fundamental means of communicating with the many elements comprising the operating environment. BIOS consists of a collection of services whose primary objective is to provide the necessary input-output support for the computing environment. Maximum flexibility is achieved by the fact that input-output support may be requested at any of several different software levels. The higher the level requested, the more work

the system does for the requester. Efficiency is also realized through the centralization of all input-output handling activities.

- Input-Output Controller Routine - BIOCTL. Provides a centralized input-output handling facility which performs the task of maintaining a coherent and responsive input-output interface. Supervision of the input-output interface is attained by handling the nonunique requirements of all input-output requests at the lowest machine level. BIOCTL maintains the status of all outstanding input-output requests, initiates all input-output activities, analyzes all input-output interrupts and accomplishes all input-output error handling.

- Device Dependent Input-Output Routine - BDVDIO. Establishes the link between an input-output request and the input-output controller. BDVDIO provides a means for processing a specific input-output request to a specific peripheral input-output device. This device-dependent processing includes constructing channel programs, initializing the specific input-output device and interrogating the device's characteristics.

- Access Method Routine - BACMTH. Converts format-dependent input-output requests to the necessary format for the device-dependent input-output routines. BACMTH consists of a series of access method subroutines to provide an input-output requester with a varied array of potential data formats. The input-output request is restructured in a manner suitable for subsequent processing by the BDVDIO routine. Access method support will be furnished for:

  Sequential access devices
  Direct access devices
  Telecommunications devices
  High-level source language input-output
  Display devices
  Realtime hardware devices

- Interdevice Input-Output Handler Routine - BIDIOH. Provides the necessary regulation required to achieve cross-system input-output. BIDIOH provides the required support to accomplish input-output between hardware components that are not dedicated to a single computer system. Specifically, this means that input-output between a CPU and a peripheral shared storage file (shared by more than one computer system) will be supported. Controls will be available to validate any data transference when this type of input-output is performed.

- Operator Query/Command Coordination Routine - BQCOMC. Provides for an essential form of communication in a computing environment, that between the operation console and the application software system. The system operates information

or action-type messages for the operator; the operator generates query or control commands for the system. BQCOMC schedules and executes commands, routes queries, manipulates message buffers, and performs error checking.

Control Program Services Module - BCPS. This module furnishes the typical system user with a useful array of services with which to exploit the power and versatility of the control program. These services are designed to assist the user by providing him with access to the system's resources and by relieving him of certain basic housekeeping duties.

- Control Program Service Request Director Routine - BCPSRQ. Acts as a central clearinghouse to assist the control program in routing requests to the appropriate service routines. BCPSRQ is a facility to coordinate the handling of requests for various control program services. Upon receipt of a request, BCPSRQ will perform preliminary and error checking prior to dispatching the request to the appropriate control program service for further processing.

- Execution Error Analyzer Routine - BEERRA. Provides a user program the capability to analyze and specify recovery procedures for errors detected during the program's execution. Normally, errors encountered during program execution will result in the termination of that program. With an error analysis feature, the program may determine that recovery from the error is possible.

- Remote Program Accessor Routine - BFETCH. Permits a user to select and call into main core storage, programs resident on peripheral storage devices. Program design and implementation is enhanced because of reduced total storage requirements. Program inquiry, selective loading, and overlay control will all be available to optimize program structure.

- Termination Coordinator Routine - BFINIS. Provides for the orderly disposition of system and user resources when a software job terminates its execution. Both scheduled and nonscheduled termination are included. The hardware and software resources allocated to the job are released, and meaningful data, representative of the system status at termination, is generated to assist the user in evaluating the job's results.

- Multiprogramming Facility Routine - BMULTI. Provides a job with a multi-programming capability. This allows the interleaved operation of more than one processing entity within a single job. This facility also provides for processing entity management, which includes creation of, dispatching of, and communication among the job's independent processing entities.

- Intermediate Result Generator Routine - BPAUSE. Provides a facility which permits a user to request intermediate results of the hardware and/or software environment during the execution of the user's program. The generated information represents the status of the system at the time the information is requested.

- Program Linkage Effector Routine - BPLINK. Provides programs operating in a dynamic environment with the means to effect different types of program-to-program linkage regardless of the desired program's current residence. Supporting this service will be a program core storage manager. The manager is responsible for maintaining the status of all programs in main core storage, requesting the loading of required nonresident programs, and purging nonessential programs from main core storage.

- System Resource Serializer Routine - BQUEUE. Provides a facility in a multiprogramming system to schedule the accessibility of certain serial resources (i. e. , not capable of servicing more than one requester at a time) among many concurrent requesters. Means of defining, reserving, and releasing these resources will be provided as part of the overall scheduling process.

- Main Storage Allocator Routine - BSTORE. Permits the efficient administration of main core storage requests on an "as needed" basis. BSTORE centralizes the management of main core storage and responds to system storage requests. This facility will assign to and reclaim from various programs main core storage obtained from an unassigned main core storage bank.

- Timing Service Routine - BTIMES. Provides a means for a requester to utilize the timing facilities of the system. Current time, either GMT or derived from some system base time, will be available. Another feature also permits a user to request the timing of a fixed time interval with some return notification of the interval expiration.

System Support Processors Module - BSSP. This module provides the tools to code, compile and modularize the application programs. BSSP supplies a series of support processors to assist the application programmers in implementing the elements of the application software system. These processors will allow software programs to be developed and maintained by using programming languages and techniques adapted to the computer hardware and the application.

- Assembler Routine - BASSEM. Provides the capability to convert machine-oriented source language statements of a user-coded routine into object code. The user has available the flexibility

and versatility of machine language, plus the auxiliary features that facilitate the preparation and documentation of a program.

- Compiler Routine - BCMPLR. Provides the capability to convert high-level source language (e. g., Fortran) statements of a user-coded routine into object code. During the compilation process, detection of error conditions will result in the generation of diagnostic error messages. These messages will then be included as part of the printout listing of the compiled source program.

- File Report Generator Routine - BFRGEN. Provides the capability of converting user-defined specifications for a file report routine into an object program. The file report routine is structured with simple source statements to perform data calculations, scan file records, write bookkeeping reports, and construct output files. BFRGEN processes the source statements and generates a machine-language, object program.

- Pre-execution Modulizer Routine - BPREXM. Transforms assembler and/or compiler object output into a form suitable for program execution. By searching libraries for necessary subroutines and resolving linkages internal to the object module, an integrated master program file complete with loading and environment information is produced.

System Utilities Module - BUTL. This module provides a wide array of utility services to monitor, maintain, and manipulate the system and user digital data bases. Such services as displaying file and volume content, creating new files, modifying file and volume content, sorting and merging of data files, and providing for recovery from catastrophic errors will be available.

- Modify File Content Routine - BALTER. Performs the collective service of altering the content of the digital data base files. The various forms of alteration include formatting, generating, and updating files in a generalized manner as opposed to the specific manner employed by the application programs in their work with the data base.

- Modify Volume Content Routine - BMANIP. Performs the collective service of manipulating the volumes of the digital data base. The various forms of manipulation include formatting by volume, relocating files on the volume, relocating files from one volume to another, and making copies by file or by volume. By utilizing these features, procedures and planning can be developed to assist in recovering from losses encountered in the data base.

- Monitor Data Base Content Routine - BNOSEY. Performs the collective service of monitoring the file and volume content

of the digital data base. The various forms of monitoring include outputting file and volume source content, member organization, and space utilization statistics. To properly maintain the system and user data base requires periodic readouts of the data base content.

- Data File Merge Routine - BMERGE. Performs generalized merging of digital data files. Where data files are structured with specified control fields (they can be either ordered or unordered), BMERGE provides for the employment of various merging techniques. Provision is also made to permit user-intervention during the merge process. With this feature, the user can regulate, alter, and summarize the file records being merged.

- Data File Sort Routine - BSORTR. Performs generalized sorting of digital data files. Different sorting techniques can be applied to data files with specified control fields. Initial input, final output, and intermediate storage may be resident on either sequential or direct access storage devices. As with BMERGE, the facility for user-intervention into the sorting process is permitted.

System Library Module - BLIB. This module provides commonly-needed services for the applications program, with a minimum amount of intervention from the user. Services for calculating arithmetic values (sine, square root, etc.) for extending system capabilities (conversion, bit manipulation, etc.) and for cataloging user data are obtained from the system library by the pre-execution modulizer 9BPREXM) as needed for a given object module.

- Arithmetic Routines - BARITH. Provides a collection of subroutines to perform arithmetic computations required by the application program. Developed as subroutines, these services can be invoked from a source external to the applications program thereby relieving the system of redundant code.

- Functional Routines - BFUNCT. Provides a collection of subroutines to perform certain functional processes for the application program. Such services as floating point arithmetic, extended precision, format conversion, and bit manipulation enhance the capabilities of the hardware and/or programming language.

- Catalog Entry Routine - BCTENT. Receives and enters into a catalog information such as time span of data and volume serial number of tape (disc) containing the data.

- Catalog Retrieval Routine - BCTRTV. Determines and returns to the caller the volume serial number of the tape (disc) containing the data for the requested time period.

Display Subsystem Module - BDSP. The display subsystem module contains those services which can be developed independent of the application in support of display devices. As such, the application is relieved of the specialized code needed to support specific devices.

- Alphanumeric Graphics Support Formatting Routine - BAGSFT. Serves as an interface between the application programs desiring to display alphanumeric data and the actual input-output performing routines. The routine checks for valid data and puts it into a format suitable for display. The routine receives and formats data from the application programs into buffers to be processed by the BAGSIO routine. This routine will invoke the BAGSIO routine when physical input-output can be performed.

- Alphanumeric Graphics Support Retrieval Routine - BAGSRT. Receives from the BAGSIO routine buffers of characters input at the display station. This routine processes the commands from the buffers and signals the subsystem identified by the command of its presence. When requested the command data is passed to the application program.

- Alphanumeric Graphics Support Input-Output Routine - BAGSIO. Sets up the input-output commands and executes them causing data transmission to/from the display device and buffers established by the display format and display retrieve routines. It provides the macro facilities for interfacing with the BAGSFT and BAGSRT routines and establishes and executes the channel programs which perform the actual transmission to/from the display device.

- Print Support Package Routines - BPRINT. Provides the application programs with the capability of producing charts and graphs which will be generated on the printer thus giving fast response without the requirement for additional offline processing.

- Teleprocessing Support Routine - BTPSUP. Allows the application programs to communicate, using teleprocessing equipment, without being concerned about the device dependent support needed. Provides an interface between the application programs and the device dependent input-output service routines for the support of teleprocessing communications.

Housekeeping Support Services Module - BHSS. This module provides a set of routines whose basic responsibility is to centralize general housekeeping duties, thereby freeing other routines from having to incorporate possible redundant logic. In this category fall the duties of protecting user data from accidental or intentional destruction, and preparing utilization statistics for the various system resources.

- File and Storage Protector Routine - BSKEEP. Safekeeper of the system's data. Data residing in main core storage are protected against accidental or intentional alteration by unauthorized application programs. Access to data residing on peripheral storage devices is protected by a lock/key technique and will require that the requester present the proper unlocking mechanism prior to gaining such access.

- System Accounting Routine - BSYACC. Gives a computing facility the concentrated information needed to plan and supervise its operations efficiently. BSYACC accounts for the use of various system resources within the computing facility. The algorithm employed will monitor the system for any change in resource status, tabulate statistics governing resource use and users, and format the statistical data for output. Examples of system resources include the CPU, input-output devices, file references, and peripheral storage usage.

TEST OLSON LAB SAMPLE NO 3 SUZUKI 250 PARAFFINS

A B

PEAK	NAME	PPMC	PCT	CARBON NO	PPM	PCT	REAC. NO.	REACT	PCT
1	METHANE	587.24	1.26	1.00	587.24	7.42	0.0	0.0	0.0
2	ETHANE	40.33	0.09	2.00	20.17	0.25	0.42	8.47	0.04
6	PROPANE	13.53	0.03	3.00	4.51	0.06	0.66	2.98	0.01
8	IB	301.95	0.65	4.00	75.49	0.95	1.05	79.26	0.38
10	NB 22DMPR	2215.80	4.74	4.50	492.40	6.22	1.27	625.35	2.98
16	IP	2825.92	6.05	5.00	565.18	7.14	1.66	938.20	4.47
19	NP	1061.48	2.27	5.00	212.30	2.68	1.58	335.43	1.60
23	22DMB	94.47	0.20	6.00	15.74	0.20	1.34	21.10	0.10
28	CP	86.08	0.18	5.00	17.22	0.22	1.56	26.86	0.13
29	23DMB	906.51	1.94	6.00	151.09	1.91	1.86	281.07	1.34
30	2MP	1085.16	2.32	6.00	180.86	2.28	1.59	287.57	1.37
31	3MP	689.16	1.48	6.00	114.86	1.45	1.64	188.37	0.90
33	NHX	716.09	1.53	6.00	119.35	1.51	1.58	188.57	0.90
37	MCP 22DMP	368.40	0.79	6.50	56.68	0.72	1.90	107.69	0.51
38	24DMP 223TMB	854.27	1.83	7.00	122.04	1.54	1.30	158.65	0.76
40	33DMP CHX	140.08	0.30	6.50	21.55	0.27	1.50	32.33	0.15
42	23DMP 2MHX	1641.14	3.51	7.00	234.45	2.96	1.50	351.67	1.68
43	3MHX UNK 4	641.38	1.37	7.00	91.63	1.16	1.50	137.44	0.66
431	UNK 4A	0.0	0.0	7.00	0.0	0.0	1.50	0.0	0.0
432	UNK 4B	70.78	0.15	7.00	10.11	0.13	1.50	15.17	0.07
433	UNK 4C	0.0	0.0	7.00	0.0	0.0	1.50	0.0	0.0
44	3EP 224TMP	3755.30	8.04	8.00	469.41	5.93	1.30	610.24	2.91
45	MHP	487.09	1.04	7.00	69.58	0.88	1.51	105.07	0.50
47	MCHX 22DMHX	155.78	0.33	7.50	20.77	0.26	1.60	33.23	0.16
471	UNK 4D	13.40	0.03	8.00	1.67	0.02	1.50	2.51	0.01
48	UNK 5	18.81	0.04	8.00	2.35	0.03	1.50	3.53	0.02
49	223TMP 25DMHX 24DMHX	1240.67	2.66	8.00	155.08	1.96	1.50	232.63	1.11
491	UNK 5B	0.0	0.0	8.00	0.0	0.0	1.50	0.0	0.0
492	UNK 5C	0.0	0.0	8.00	0.0	0.0	1.50	0.0	0.0
50	33DMHX 234TMP 233TMP 23DMHX	3362.68	7.20	8.00	420.33	5.31	1.60	672.54	3.21
51	UNK 6	415.50	0.89	8.00	51.94	0.66	1.50	77.91	0.37
52	UNK 7	327.25	0.70	8.00	40.91	0.52	1.50	61.36	0.29
53	3MHP	203.42	0.44	8.00	25.43	0.32	1.63	41.45	0.20
54	225TMHX T12DMCHX	687.80	1.47	8.00	85.98	1.09	1.60	137.56	0.66
541	UNK 9A	0.0	0.0	9.00	0.0	0.0	1.50	0.0	0.0
542	UNK 9B	2.98	0.01	8.00	0.37	0.00	1.50	0.56	0.00
55	NOC	151.72	0.32	8.00	18.96	0.24	1.46	27.69	0.13
56	UNK 10	0.0	0.0	9.00	0.0	0.0	1.50	0.0	0.0
57	UNK 11	92.57	0.20	9.00	10.29	0.13	1.50	15.43	0.07
59	C12DMCHX	12.99	0.03	8.00	1.62	0.02	1.70	2.76	0.01
60	UNK 12	12.99	0.03	9.00	1.44	0.02	1.50	2.17	0.01
61	UNK 13	20.98	0.04	9.00	2.33	0.03	1.50	3.50	0.02
62	UNK 15	44.12	0.09	9.00	4.90	0.06	1.50	7.35	0.04
63	UNK 17	10.83	0.02	9.00	1.20	0.02	1.50	1.80	0.01
64	UNK 18	26.80	0.06	9.00	2.98	0.04	1.50	4.47	0.02
65	UNK 19	54.81	0.12	9.00	6.09	0.08	1.50	9.14	0.04
651	UNK 19A	60.63	0.13	9.00	6.74	0.09	1.50	10.11	0.05
652	UNK 19B	0.0	0.0	9.00	0.0	0.0	1.50	0.0	0.0
66	UNK 20	0.0	0.0	9.00	0.0	0.0	1.50	0.0	0.0

66	UNK 20	0.0	0.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
67	UNK 21	59.41	0.13	9.00	6.60	0.08	1.50	9.90	0.05
68	UNK 22	20.99	0.04	9.00	2.33	0.03	1.50	3.50	0.02
69	NN	64.56	0.14	9.00	7.17	0.07	1.42	10.19	0.05
70	UNK 25	4.06	0.01	10.00	0.41	0.01	1.50	0.61	0.00
71	UNK 26	1.62	0.00	10.00	0.16	0.00	1.50	0.24	0.00
72	UNK 28	2.71	0.01	10.00	0.27	0.00	1.50	0.41	0.00
73	UNK 30	1.22	0.00	10.00	0.12	0.00	1.50	0.18	0.00
74	UNK 31	0.0	0.0	10.00	0.0	0.0	1.50	0.0	0.0
75	UNK 32	2.71	0.01	10.00	0.27	0.00	1.50	0.41	0.00
76	UNK 33	10.96	0.02	10.00	1.10	0.01	1.50	1.64	0.01
77	UNK 34	1.35	0.00	10.00	0.14	0.00	1.50	0.20	0.00
78	UNK 35	0.0	0.0	10.00	0.0	0.0	1.50	0.0	0.0
79	NO	23.14	0.05	10.00	2.31	0.03	1.40	3.24	0.02
80	UNK 37	1.76	0.00	11.00	0.16	0.00	1.50	0.24	0.00
81	UNK 38	0.0	0.0	11.00	0.0	0.0	1.50	0.0	0.0
82	UNK 39	0.0	0.0	11.00	0.0	0.0	1.50	0.0	0.0
83	UNK 40	0.0	0.0	11.00	0.0	0.0	1.50	0.0	0.0
84	UNK 41	0.0	0.0	11.00	0.0	0.0	1.50	0.0	0.0
85	OTHER PARAFFINS	5.41	0.01	11.50	0.47	0.01	1.50	0.71	0.00
	TOTAL	25698.69	55.03		4514.70	57.03		5880.47	28.04
	AVERAGE			5.69			1.30		

TEST OLSON LAB SAMPLE NO 3 SUZUKI 250

TEST OLSON LAB SAMPLE NO 3 SUZUKI 250 OLEFINS

PEAK	NAME	PPMC	PCT	CARBON NO	PPM	PCT	REAC. NO.	REACT	PCT
3	ETHYLENE	429.55	0.92	2.00	214.78	2.71	2.88	618.55	2.95
5	PROPYLENE	205.61	0.44	3.00	68.54	0.87	5.93	406.42	1.94
7	PROPADIENE	13.44	0.03	3.00	4.48	0.06	3.90	17.48	0.08
9	1B IBE 13B	189.57	0.41	4.00	47.39	0.60	6.04	286.25	1.36
11	T2B	98.68	0.21	4.00	24.67	0.31	18.98	468.24	2.23
12	UNK 1	6.11	0.01	4.00	1.53	0.02	15.00	22.91	0.11
13	C2B	56.83	0.12	4.00	14.21	0.18	12.03	170.90	0.81
14	UNK 1A2	1.53	0.00	4.00	0.38	0.00	4.00	1.53	0.01
15	3M1B	41.09	0.09	5.00	8.22	0.10	4.58	37.64	0.18
17	1P	81.57	0.17	5.00	16.31	0.21	3.56	58.08	0.28
18	2M1B	169.41	0.36	5.00	33.88	0.43	5.76	195.16	0.93
20	2M13B	0.0	0.0	5.00	0.0	0.0	6.27	0.0	0.0
21	T2P	193.08	0.41	5.00	38.62	0.49	13.05	503.95	2.40
22	C2P	96.39	0.21	5.00	19.28	0.24	9.15	176.39	0.84
23	2M2B	348.44	0.75	5.00	69.69	0.88	32.20	2243.93	10.70
24	T13P	18.64	0.04	5.00	3.73	0.05	6.80	25.35	0.12
25	UNK 2	0.0	0.0	5.00	0.0	0.0	4.00	0.0	0.0
26	C13P	0.0	0.0	5.00	0.0	0.0	6.80	0.0	0.0
27	CPE	35.44	0.08	5.00	7.09	0.09	38.98	276.29	1.32
28	4M1P	36.86	0.08	6.00	6.14	0.08	3.90	23.96	0.11
29	23DM1B	40.97	0.09	6.00	6.83	0.09	3.73	25.47	0.12
291	UNK 2A2	0.0	0.0	6.00	0.0	0.0	4.00	0.0	0.0
30	4MT2P	63.15	0.14	6.00	10.53	0.13	6.61	69.57	0.33
301	4MC2P	0.0	0.0	6.00	0.0	0.0	6.50	0.0	0.0
31	UNK 3	3.56	0.01	6.00	0.59	0.01	4.00	2.37	0.01
32	2M1P 1HX	104.33	0.22	6.00	17.39	0.22	3.39	58.95	0.28
33	2E1B	17.40	0.04	5.00	2.90	0.04	3.90	11.31	0.05
34	C3HX T3HX T2HX	177.96	0.39	6.00	29.66	0.37	8.40	249.15	1.19
35	2M2P 3MT2P	184.53	0.40	6.00	30.75	0.39	27.12	834.07	3.98
36	23DM13B C2HX	39.26	0.08	6.00	6.54	0.08	20.30	132.87	0.63
37	3MC2P	96.00	0.21	6.00	16.00	0.20	17.00	272.00	1.30
371	UNK 3A2	0.0	0.0	6.00	0.0	0.0	25.00	0.0	0.0
38	23DM2B 233TM1B	33.03	0.07	6.50	5.08	0.06	52.90	268.70	1.28
381	UNK 3B2	0.0	0.0	7.00	0.0	0.0	25.00	0.0	0.0
39	1MCPE 34DM1P	0.0	0.0	6.50	0.0	0.0	25.00	0.0	0.0
41	5M1HX	14.05	0.03	7.00	2.01	0.03	2.50	5.02	0.02
411	UNK 3C2	5.96	0.01	7.00	0.85	0.01	2.50	2.13	0.01
42	CHXE	83.39	0.18	6.00	13.90	0.18	5.93	82.42	0.39
43	5MT2HX 34DMC2P 5MC2HX 34DMT2P	76.95	0.16	7.00	10.99	0.14	11.00	120.91	0.58
431	UNK 4A2	0.0	0.0	7.00	0.0	0.0	10.00	0.0	0.0
432	UNK 4B2	0.0	0.0	7.00	0.0	0.0	10.00	0.0	0.0
433	UNK 4C2	0.0	0.0	7.00	0.0	0.0	10.00	0.0	0.0
44	2M1HX 1HP	0.0	0.0	7.00	0.0	0.0	2.80	0.0	0.0
441	UNK 4D2	61.41	0.13	7.00	8.77	0.11	7.00	61.41	0.29
45	2M2HX T3HP C3HP	78.96	0.17	7.00	11.26	0.14	11.30	127.46	0.61
451	UNK 4E2	0.0	0.0	7.00	0.0	0.0	10.00	0.0	0.0
46	244TM1P 3E2P T2HP	45.22	0.10	7.33	6.17	0.08	9.40	57.98	0.28
461	UNK 4F2	0.0	0.0	7.00	0.0	0.0	10.00	0.0	0.0
[illegible]	[illegible]	31.62	0.07	7.00	4.52	0.06	47.00	212.30	1.01

47	23DM2P C2HP	31.62	0.07	7.00	4.52	0.06	47.00	212.30	1.01
471	UNK 4G2	0.0	0.0	7.00	0.0	0.0	30.00	0.0	0.0
48	UNK 5A2	0.0	0.0	7.00	0.0	0.0	30.00	0.0	0.0
49	244TM2P 4MCHXE 3MCHXE	96.91	0.21	7.33	13.22	0.17	13.00	171.87	0.82
491	UNK 5B2	0.0	0.0	7.33	0.0	0.0	13.00	0.0	0.0
492	UNK 5C2	0.0	0.0	7.33	0.0	0.0	13.00	0.0	0.0
51	1MCHXE	228.83	0.49	7.00	32.69	0.41	9.73	318.07	1.52
52	UNK 8	92.03	0.20	8.00	11.50	0.15	7.00	80.53	0.38
53	UNK 9	96.93	0.21	8.00	12.12	0.15	7.00	84.82	0.40
54	1OC 2E1HX	112.76	0.24	8.00	14.10	0.18	2.80	39.47	0.19
541	UNK 9A2	15.28	0.03	8.00	1.91	0.02	2.50	4.77	0.02
542	UNK 9B2	16.24	0.03	8.00	2.03	0.03	2.50	5.07	0.02
55	23DM2HX T4OC 2M2HP	9.10	0.02	8.00	1.14	0.01	27.85	31.69	0.15
56	UNK 9C2	29.63	0.06	8.00	3.70	0.05	7.00	25.93	0.12
57	26DM3HP	37.26	0.08	9.00	4.14	0.05	6.80	28.15	0.13
58	T2OC C2OC	0.0	0.0	8.00	0.0	0.0	4.80	0.0	0.0
60	4EECHXE	1.26	0.00	8.00	0.16	0.00	3.05	0.48	0.00
601	UNK 13A2	0.0	0.0	8.00	0.0	0.0	6.00	0.0	0.0
61	UNK 14	11.00	0.02	9.00	1.22	0.02	6.00	7.33	0.03
611	UNK 14A2	0.0	0.0	9.00	0.0	0.0	6.00	0.0	0.0
62	UNK 16	35.32	0.08	9.00	3.92	0.05	6.00	23.55	0.11
621	UNK 16A2	0.0	0.0	9.00	0.0	0.0	6.00	0.0	0.0
631	UNK 17A2	0.0	0.0	9.00	0.0	0.0	6.00	0.0	0.0
65	12DMCHXE	76.57	0.16	8.00	9.57	0.12	15.42	147.59	0.70
651	UNK 19A2	0.0	0.0	9.00	0.0	0.0	6.00	0.0	0.0
67	UNK 21A2	53.73	0.12	9.00	5.97	0.08	6.00	35.82	0.17
68	UNK 23	69.81	0.15	9.00	7.76	0.10	6.00	46.54	0.22
69	UNK 24	55.79	0.12	9.00	6.20	0.08	6.00	37.19	0.18
691	UNK 24A2	0.0	0.0	10.00	0.0	0.0	6.00	0.0	0.0
71	UNK 27	37.14	0.08	10.00	3.71	0.05	6.00	22.29	0.11
711	UNK 27A2	0.0	0.0	10.00	0.0	0.0	6.00	0.0	0.0
72	UNK 29	8.29	0.02	10.00	0.83	0.01	6.00	4.97	0.02
721	UNK 29A2	6.57	0.01	10.00	0.66	0.01	6.00	3.94	0.02
741	UNK 31A2	0.0	0.0	10.00	0.0	0.0	6.00	0.0	0.0
85	OTHER OLEFINS	0.0	0.0	11.00	0.0	0.0	6.00	0.0	0.0
	TOTAL	4270.41	9.14		900.23	11.37		9247.14	44.09
	AVERAGE			4.74			10.27		

TEST OLSON LAB SAMPLE NO 3 SUZUKI 250

TEST OLSON LAB SAMPLE NO 3 SUZUKI 250

AROMATICS

PEAK	NAME	PPMC	PCT	CARBON NO	PPM	PCT	REAC. NO.	REACT	PCT
39	BZ	1243.25	2.66	6.00	207.21	2.62	0.56	116.04	0.55
50	TOL	7444.21	15.94	7.00	1063.46	13.43	2.20	2339.61	11.16
63	EBZ	691.83	1.48	8.00	86.48	1.09	2.03	175.55	0.84
64	PX MX	1882.07	4.03	8.00	235.26	2.97	4.92	1157.47	5.52
652	PHEE (STYRENE)	0.0	0.0	8.00	0.0	0.0	3.50	0.0	0.0
66	OX	877.36	1.88	8.00	109.67	1.39	3.64	399.20	1.90
70	IPRBZ	32.61	0.07	9.00	3.62	0.05	1.64	5.94	0.03
73	NPRBZ	181.64	0.39	9.00	20.18	0.25	1.70	34.31	0.16
74	1M3EBZ 1M4EBZ	695.74	1.49	9.00	77.30	0.98	4.10	316.95	1.51
75	135TMBZ	259.99	0.56	9.00	28.89	0.36	8.64	249.50	1.19
751	UNK 32A3	0.0	0.0	10.00	0.0	0.0	6.00	0.0	0.0
76	1M2EBZ 2PH1PR	391.61	0.84	9.00	43.51	0.55	3.40	147.94	0.71
761	UNK 33A3	0.0	0.0	10.00	0.0	0.0	6.00	0.0	0.0
77	C1PH1PR TBBZ 124TMBZ	904.06	1.94	9.33	96.90	1.22	3.20	310.07	1.49
78	IBBZ SBBZ	47.08	0.10	10.00	4.71	0.06	1.00	4.71	0.02
79	UNK 36	7.44	0.02	9.50	0.78	0.01	5.00	3.91	0.02
80	1M3IPRBZ 123TMBZ	154.12	0.33	9.50	16.22	0.20	5.80	94.09	0.45
81	1M4IPRBZ T1PH1PR	54.77	0.12	9.50	5.76	0.07	3.00	17.29	0.08
82	1M2IPRBZ	21.65	0.05	10.00	2.17	0.03	2.90	6.28	0.03
83	13DEBZ 1M3NPRBZ	179.10	0.38	10.00	17.91	0.23	4.20	75.22	0.36
84	1M4NPRBZ NBBZ 12DEBZ 13DM5EBZ 14DEBZ	71.39	0.15	10.00	7.14	0.09	3.40	24.27	0.12
85	OTHER AROMATICS	782.71	1.68	11.00	71.16	0.90	5.00	355.78	1.70
	TOTAL	15922.49	34.09		2098.32	26.50		5834.11	27.82
	AVERAGE			7.59			2.78		

ACETYLENES

PEAK	NAME	PPMC	PCT	CARBON NO	PPM	PCT	REAC. NO.	REACT	PCT
4	ACETYLENE	803.33	1.72	2.00	401.66	5.07	0.0	0.0	0.0
107	MA	8.24	0.02	3.00	2.75	0.03	3.90	10.72	0.05
13	EA WITH C2B	0.0	0.0	4.00	0.0	0.0	18.98	0.0	0.0
	TOTAL	811.57	1.74		404.41	5.11		10.72	0.05
	AVERAGE			2.01			0.03		

GRAND TOTALS PPMC PPM REACTIVITY

******** 46702.89 7917.520 ******** 20972.50

AS HEXANE 7783.844

MAGA INDEX 0.674
GM INDEX 2.649
AVE. C NUMBER 5.899

J.

TEST OLSON LAB SAMPLE NO 2 YAMAHA 305

AROMATICS

PEAK	NAME	PPMC	PCT	CARBON NO	PPM	PCT	REAC. NO.	REACT	PCT
39	BZ	1012.61	2.0[illegible]	6.00	169.77	1.95	0.56	94.51	0.30
50	TOL	5212.02	10.44	7.00	744.57	8.62	2.20	1638.06	5.18
63	EBZ	758.78	1.52	8.00	94.85	1.10	2.03	192.54	0.61
64	PX MX	2384.00	4.78	8.00	298.00	3.45	4.92	1466.16	4.64
652	PHEE (STYRENE)	0.0	0.0	8.00	0.0	0.0	3.50	0.0	0.0
66	OX	1161.80	2.33	8.00	145.22	1.68	3.64	528.62	1.67
70	IPRBZ	45.85	0.09	9.00	5.09	0.06	1.64	8.35	0.03
73	NPRBZ	307.87	0.62	9.00	34.21	0.40	1.70	58.15	0.18
74	1M3EBZ 1M4EBZ	1303.95	2.61	9.00	144.88	1.68	4.10	594.02	1.88
75	135TMBZ	565.99	1.13	9.00	62.89	0.73	8.64	543.35	1.72
751	UNK 32A3	0.0	0.0	10.00	0.0	0.0	6.00	0.0	0.0
76	1M2EBZ 2PH1PR	668.96	1.34	9.00	74.33	0.86	3.40	252.72	0.80
761	UNK 33A3	73.72	0.15	10.00	7.37	0.09	6.00	44.23	0.14
77	C1PH1PR TBBZ 124TMBZ	1945.18	3.90	9.33	208.49	2.41	3.20	667.16	2.11
78	IBBZ SBBZ	139.24	0.28	10.00	13.92	0.16	1.00	13.92	0.04
79	UNK 36	70.54	0.14	9.50	7.42	0.09	5.00	37.12	0.12
80	1M3IPRBZ 123TMBZ	426.17	0.85	9.50	44.86	0.52	5.80	260.19	0.82
81	1M4IPRBZ T1PH1PR	202.68	0.41	9.50	21.34	0.25	3.00	64.01	0.20
82	1M2IPRBZ	138.90	0.28	10.00	13.89	0.16	2.90	40.28	0.13
83	13DEBZ 1M3NPRBZ	401.79	0.81	10.00	40.18	0.47	4.20	168.75	0.53
84	1M4NPRBZ NBBZ 12DEBZ 13DM5EBZ 14DEBZ	189.40	0.38	10.00	18.94	0.22	3.40	64.39	0.20
85	OTHER AROMATICS	1767.85	3.54	11.00	160.71	1.86	5.00	803.57	2.54
	TOTAL	18777.27	37.62		2309.94	26.74		7540.09	23.85
	AVERAGE			8.13			3.26		

TEST OLSON LAB SAMPLE NO 2 YAMAHA 305

ACETYLENES

PEAK	NAME	PPMC	PCT	CARBON NO	PPM	PCT	REAC. NO.	REACT	PCT
4	ACETYLENE	709.98	1.42	2.00	354.99	4.11	0.0	0.0	0.0
107	MA	18.60	0.04	3.00	6.20	0.07	3.90	24.18	0.08
13	EA WITH C28	0.0	0.0	4.00	0.0	0.0	18.98	0.0	0.0
	TOTAL	728.57	1.46		361.19	4.18		24.18	0.08
	AVERAGE			2.02			0.07		

GRAND TOTALS	PPMC	PPM	REACTIVITY
	******** 49910.82	8636.875	******** 31616.88
AS HEXANE	8318.500		

MAGA INDEX 0.723
GM INDEX 3.661
AVE. C NUMBER 5.779

451	UNK 4E2	0.0	0.0	7.00	0.0	0.0	10.00	0.0	0.0
46	244TM1P 3E2P T2HP	119.65	0.24	7.33	16.32	0.19	9.40	153.44	0.49
461	UNK 4F2	40.18	0.08	7.00	5.74	0.07	10.00	57.40	0.18
47	23DM2P C2HP	99.08	0.20	7.00	14.15	0.16	47.00	665.25	2.10
471	UNK 4G2	0.0	0.0	7.00	0.0	0.0	30.00	0.0	0.0
48	UNK 5A2	27.55	0.06	7.00	3.94	0.05	30.00	118.07	0.37
49	244TM2P 4MCHXE 3MCHXE	110.35	0.22	7.33	15.05	0.17	13.00	195.71	0.62
491	UNK 5B2	0.0	0.0	7.33	0.0	0.0	13.00	0.0	0.0
492	UNK 5C2	0.0	0.0	7.33	0.0	0.0	13.00	0.0	0.0
51	1MCHXE	258.87	0.52	7.00	36.98	0.43	9.73	359.83	1.14
52	UNK 8	124.30	0.25	8.00	15.54	0.18	7.00	108.77	0.34
53	UNK 9	195.47	0.39	8.00	24.43	0.28	7.00	171.04	0.54
54	10C 2E1HX	150.70	0.30	8.00	18.84	0.22	2.80	52.75	0.17
541	UNK 9A2	76.65	0.15	8.00	9.58	0.11	2.50	23.95	0.08
542	UNK 9B2	73.11	0.15	8.00	9.14	0.11	2.50	22.85	0.07
55	23DM2HX T40C 2M2HP	58.63	0.12	8.00	7.33	0.08	27.85	204.11	0.65
56	UNK 9C2	64.94	0.13	8.00	8.12	0.09	7.00	56.83	0.18
57	26DM3HP	61.76	0.12	9.00	6.86	0.08	6.80	46.66	0.15
58	T20C C20C	0.0	0.0	8.00	0.0	0.0	4.80	0.0	0.0
60	4EECHXE	14.03	0.03	8.00	1.75	0.02	3.05	5.35	0.02
601	UNK 13A2	0.0	0.0	8.00	0.0	0.0	6.00	0.0	0.0
61	UNK 14	22.92	0.05	9.00	2.55	0.03	6.00	15.28	0.05
611	UNK 14A2	0.0	0.0	9.00	0.0	0.0	6.90	0.0	0.0
62	UNK 16	69.12	0.14	9.00	7.68	0.09	6.00	46.08	0.15
621	UNK 16A2	0.0	0.0	9.00	0.0	0.0	6.00	0.0	0.0
631	UNK 17A2	0.0	0.0	9.00	0.0	0.0	6.00	0.0	0.0
65	12DMCHXE	160.70	0.32	8.00	20.09	0.23	15.42	309.75	0.98
651	UNK 19A2	0.0	0.0	7.00	0.0	0.0	6.00	0.0	0.0
67	UNK 21A2	107.04	0.21	9.00	11.89	0.14	6.00	71.36	0.23
68	UNK 23	111.59	0.22	9.00	12.40	0.14	6.00	74.39	0.24
69	UNK 24	140.38	0.28	9.00	15.60	0.18	6.00	93.59	0.30
691	UNK 24A2	0.0	0.0	10.00	0.0	0.0	6.00	0.0	0.0
71	UNK 27	35.77	0.07	10.00	3.58	0.04	6.00	21.46	0.07
711	UNK 27A2	0.0	0.0	10.00	0.0	0.0	6.00	0.0	0.0
72	UNK 29	43.99	0.09	10.00	4.40	0.05	6.00	26.39	0.08
721	UNK 29A2	13.77	0.03	10.00	1.38	0.02	6.00	8.26	0.03
741	UNK 31A2	0.0	0.0	10.00	0.0	0.0	6.00	0.0	0.0
85	OTHER OLEFINS	0.0	0.0	11.00	0.0	0.0	6.00	0.0	0.0
	TOTAL	8990.99	18.01		2007.28	23.24		*******	60.09
	AVERAGE			4.48			9.46	18998.6	

TEST OLSON LAB SAMPLE NO 2 YAMAHA 305

TEST OLSON LAB SAMPLE NO 2 YAMAHA 305 OLEFINS

PEAK	NAME	PPMC	PCT	CARBON NO	PPM	PCT	REAC. NO.	REACT	PCT
3	ETHYLENE	1092.16	2.19	2.00	546.08	6.32	2.88	1572.71	4.97
5	PROPYLENE	634.52	1.27	3.00	211.51	2.45	5.93	1254.24	3.97
7	PROPADIENE	25.02	0.05	3.00	8.34	0.10	3.90	32.52	0.10
9	1B IBE 13B	579.69	1.16	4.00	144.92	1.68	6.04	875.33	2.77
11	T2B	172.85	0.35	4.00	43.21	0.50	18.98	820.15	2.59
12	UNK 1	17.18	0.03	4.00	4.30	0.05	15.00	64.44	0.20
13	C2B	140.63	0.28	4.00	35.16	0.41	12.03	422.93	1.34
14	UNK 1A2	1.90	0.00	4.00	0.47	0.01	4.00	1.90	0.01
15	3M1B	69.62	0.14	5.00	13.92	0.16	4.58	63.77	0.20
17	1P	173.73	0.35	5.00	34.75	0.40	3.56	123.70	0.39
18	2M1B	308.04	0.62	5.00	61.61	0.71	5.76	354.86	1.12
20	2M13B	94.89	0.19	5.00	18.98	0.22	6.27	118.99	0.38
21	T2P	336.47	0.67	5.00	67.29	0.78	13.05	878.18	2.78
22	C2P	176.26	0.35	5.00	35.25	0.41	9.15	322.55	1.02
23	2M2B	614.31	1.23	5.00	122.86	1.42	32.20	3956.15	12.51
24	T13P	58.25	0.12	5.00	11.65	0.13	6.80	79.22	0.25
25	UNK 2	6.93	0.01	5.00	1.39	0.02	4.00	5.54	0.02
26	C13P	0.0	0.0	5.00	0.0	0.0	6.80	0.0	0.0
27	CPE	84.91	0.17	5.00	16.98	0.20	38.98	661.93	2.09
28	4M1P	66.82	0.13	6.00	11.14	0.13	3.90	43.43	0.14
29	23DM1B	61.50	0.12	6.00	10.25	0.12	3.73	38.23	0.12
291	UNK 2A2	0.0	0.0	6.00	0.0	0.0	4.00	0.0	0.0
30	4MT2P	119.11	0.24	6.00	19.85	0.23	6.61	131.22	0.42
301	4MC2P	0.0	0.0	6.00	0.0	0.0	6.50	0.0	0.0
31	UNK 3	39.27	0.08	6.00	6.55	0.08	4.00	26.18	0.08
32	2M1P 1HX	223.64	0.45	6.00	37.27	0.43	3.39	126.36	0.40
33	2E1B	17.47	0.03	6.00	2.91	0.03	3.90	11.35	0.04
34	C3HX T3HX T2HX	299.95	0.60	6.00	49.99	0.58	8.40	419.93	1.33
35	2M2P 3MT2P	304.75	0.61	6.00	50.79	0.59	27.12	1377.49	4.36
36	23DM13B C2HX	77.45	0.16	6.00	12.91	0.15	20.30	262.05	0.83
37	3MC2P	177.56	0.36	6.00	29.59	0.34	17.00	503.09	1.59
371	UNK 3A2	0.0	0.0	6.00	0.0	0.0	25.00	0.0	0.0
38	23DM2B 233TM1B	71.42	0.14	6.50	10.99	0.13	52.90	581.21	1.84
381	UNK 3B2	18.07	0.04	7.00	2.58	0.03	25.00	64.53	0.20
39	1MCPE 34DM1P	0.0	0.0	6.50	0.0	0.0	25.00	0.0	0.0
41	5M1HX	59.76	0.12	7.00	8.54	0.10	2.50	21.34	0.07
411	UNK 3C2	28.81	0.06	7.00	4.12	0.05	2.50	10.29	0.03
42	CHXE	162.35	0.33	6.00	27.06	0.31	5.93	160.46	0.51
43	5MT2HX 34DMC2P 5MC2HX 34DMT2P	63.32	0.13	7.00	9.05	0.10	11.00	99.50	0.31
431	UNK 4A2	0.0	0.0	7.00	0.0	0.0	10.00	0.0	0.0
432	UNK 4B2	0.0	0.0	7.00	0.0	0.0	10.00	0.0	0.0
433	UNK 4C2	134.31	0.27	7.00	19.19	0.22	10.00	191.87	0.61
44	2M1HX 1HP	0.0	0.0	7.00	0.0	0.0	2.80	0.0	0.0
441	UNK 4D2	110.56	0.22	7.00	15.79	0.18	7.00	110.56	0.35
45	2M2HX T3HP C3HP	187.06	0.37	7.00	26.72	0.31	11.30	301.96	0.96
451	UNK 4E2	0.0	0.0	7.00	0.0	0.0	10.00	0.0	0.0
46	244TM1P 3E2P T2HP	119.65	0.24	7.33	16.32	0.19	9.40	153.44	0.49
461	UNK 4F2	40.18	0.08	7.00	5.74	0.07	10.00	57.40	0.18

E

F

TEST OLSON LAB SAMPLE NO 2 YAMAHA 305 OLEFINS

PEAK	NAME	PPMC	PCT	CARBON NO	PPM	PCT	REAC. NO.	REACT	PCT
3	ETHYLENE	1092.16	2.19	2.00	546.08	6.32	2.88	1572.71	4.97
5	PROPYLENE	634.52	1.27	3.00	211.51	2.45	5.93	1254.24	3.97
7	PROPADIENE	25.02	0.05	3.00	8.34	0.10	3.90	32.52	0.10
9	1B IBE 13B	579.69	1.16	4.00	144.92	1.68	6.04	875.33	2.77
11	T2B	172.85	0.35	4.00	43.21	0.50	18.98	820.15	2.59
12	UNK 1	17.18	0.03	4.00	4.30	0.05	15.00	64.44	0.20
13	C2B	140.63	0.28	4.00	35.16	0.41	12.03	422.93	1.34
14	UNK 1A2	1.90	0.00	4.00	0.47	0.01	4.00	1.90	0.01
15	3M1B	69.62	0.14	5.00	13.92	0.16	4.58	63.77	0.20
17	1P	173.73	0.35	5.00	34.75	0.40	3.56	123.70	0.39
18	2M1B	308.04	0.62	5.00	61.61	0.71	5.76	354.86	1.12
20	2M13B	94.89	0.19	5.00	18.98	0.22	6.27	118.99	0.38
21	T2P	336.47	0.67	5.00	67.29	0.78	13.05	878.18	2.78
22	C2P	176.26	0.35	5.00	35.25	0.41	9.15	322.55	1.02
23	2M2B	614.31	1.23	5.00	122.86	1.42	32.20	3956.15	12.51
24	T13P	58.25	0.12	5.00	11.65	0.13	6.80	79.22	0.25
25	UNK 2	6.93	0.01	5.00	1.39	0.02	4.00	5.54	0.02
26	C13P	0.0	0.0	5.00	0.0	0.0	6.80	0.0	0.0
27	CPE	84.91	0.17	5.00	16.98	0.20	38.98	661.93	2.09
28	4M1P	66.82	0.13	6.00	11.14	0.13	3.90	43.43	0.14
29	23DM1B	61.50	0.12	6.00	10.25	0.12	3.73	38.23	0.12
291	UNK 2A2	0.0	0.0	6.00	0.0	0.0	4.00	0.0	0.0
30	4MT2P	119.11	0.24	6.00	19.85	0.23	6.61	131.22	0.42
301	4MC2P	0.0	0.0	6.00	0.0	0.0	6.50	0.0	0.0
31	UNK 3	39.27	0.08	6.00	6.55	0.08	4.00	26.18	0.08
32	2M1P 1HX	223.64	0.45	6.00	37.27	0.43	3.39	126.36	0.40
33	2E1B	17.47	0.03	6.00	2.91	0.03	3.90	11.35	0.04
34	C3HX T3HX T2H	299.95	0.60	6.00	49.99	0.58	8.40	419.93	1.33
35	2M2P 3MT2P	304.75	0.61	6.00	50.79	0.59	27.12	1377.49	4.36
36	23DM13B C2HX	77.45	0.16	6.00	12.91	0.15	20.30	262.05	0.83
37	3MC2P	177.56	0.36	6.00	29.59	0.34	17.00	503.09	1.59
371	UNK 3A2	0.0	0.0	6.00	0.0	0.0	25.00	0.0	0.0
38	23DM2B 233TM1B	71.42	0.14	6.50	10.99	0.13	52.90	581.21	1.84
381	UNK 3B2	18.07	0.04	7.00	2.58	0.03	25.00	64.53	0.20
39	1MCPE 34DM1P	0.0	0.0	6.50	0.0	0.0	25.00	0.0	0.0
41	5M1HX	59.76	0.12	7.00	8.54	0.10	2.50	21.34	0.07
411	UNK 3C2	28.81	0.06	7.00	4.12	0.05	2.50	10.29	0.03
42	CHXE	162.35	0.33	6.00	27.06	0.31	5.93	160.46	0.51
43	5MT2HX 34DMC2P 5MC2HX 34DMT2P	63.32	0.13	7.00	9.05	0.10	11.00	99.50	0.31
431	UNK 4A2	0.0	0.0	7.00	0.0	0.0	10.00	0.0	0.0
432	UNK 4B2	0.0	0.0	7.00	0.0	0.0	10.00	0.0	0.0
433	UNK 4C2	134.31	0.27	7.00	19.19	0.22	10.00	191.87	0.61
44	2M1HX 1HP	0.0	0.0	7.00	0.0	0.0	2.80	0.0	0.0
441	UNK 4D2	110.56	0.22	7.00	15.79	0.18	7.00	110.56	0.35
45	2M2HX T3HP C3HP	187.06	0.37	7.00	26.72	0.31	11.30	301.96	0.96

AVE. C NUMBER 5.779

67	UNK 21	36.38	0.07	9.00	4.04	0.05	1.50	6.06	0.02
68	UNK 22	2.70	0.01	9.00	0.30	0.00	1.50	0.45	0.00
69	NN	99.80	0.20	9.00	11.09	0.13	1.42	15.75	0.05
70	UNK 25	12.62	0.03	10.00	1.26	0.01	1.50	1.89	0.01
71	UNK 26	2.25	0.00	10.00	0.23	0.00	1.50	0.34	0.00
72	UNK 28	2.25	0.00	10.00	0.23	0.00	1.50	0.34	0.00
73	UNK 30	3.72	0.01	10.00	0.37	0.00	1.50	0.56	0.00
74	UNK 31	2.70	0.01	10.00	0.27	0.00	1.50	0.41	0.00
75	UNK 32	0.23	0.00	10.00	0.02	0.00	1.50	0.03	0.00
76	UNK 33	34.36	0.07	10.00	3.44	0.04	1.50	5.15	0.02
77	UNK 34	4.39	0.01	10.00	0.44	0.01	1.50	0.66	0.00
78	UNK 35	0.0	0.0	10.00	0.0	0.0	1.50	0.0	0.0
79	ND	88.88	0.18	10.00	8.89	0.10	1.40	12.44	0.04
80	UNK 37	0.0	0.0	11.00	0.0	0.0	1.50	0.0	0.0
81	UNK 38	0.0	0.0	11.00	0.0	0.0	1.50	0.0	0.0
82	UNK 39	0.0	0.0	11.00	0.0	0.0	1.50	0.0	0.0
83	UNK 40	0.0	0.0	11.00	0.0	0.0	1.50	0.0	0.0
84	UNK 41	0.0	0.0	11.00	0.0	0.0	1.50	0.0	0.0
85	OTHER PARAFFINS	45.06	0.09	11.50	3.92	0.05	1.50	5.88	0.02
	TOTAL	21414.20	42.90		3958.61	45.83		5053.94	15.99
	AVERAGE			5.41			1.28		

C D

TEST OLSON LAB SAMPLE NO 2 YAMAHA 305

TEST OLSON LAB SAMPLE NO 2 YAMAHA 305

PARAFFINS

A B

PEAK	NAME	PPMC	PCT	CARBON NO	PPM	PCT	REAC. NO.	REACT	PCT
1	METHANE	607.94	1.22	1.00	607.94	7.04	0.0	0.0	0.0
2	ETHANE	124.81	0.25	2.00	62.40	0.72	0.42	26.21	0.08
6	PROPANE	17.46	0.03	3.00	5.82	0.07	0.66	3.84	0.01
8	IB	169.08	0.34	4.00	42.27	0.49	1.05	44.38	0.14
10	NB 22DMPR	1457.95	2.92	4.50	323.99	3.75	1.27	411.47	1.30
16	IP	2676.42	5.36	5.00	535.28	6.20	1.66	888.57	2.81
19	NP	1305.88	2.62	5.00	261.18	3.02	1.58	412.66	1.31
25	22DMB	62.74	0.13	6.00	10.46	0.12	1.34	14.01	0.04
28	CP	129.43	0.26	5.00	25.89	0.30	1.56	40.38	0.13
29	23DMB	604.11	1.21	6.00	100.68	1.17	1.86	187.27	0.59
30	2MP	1260.15	2.52	6.00	210.02	2.43	1.59	333.94	1.06
31	3MP	786.03	1.57	6.00	131.00	1.52	1.64	214.85	0.68
33	NHX	957.14	1.92	6.00	159.52	1.85	1.58	252.05	0.80
37	MCP 22DMP	629.79	1.26	6.50	96.89	1.12	1.90	184.09	0.58
38	24DMP 223TMB	545.99	1.09	7.00	78.00	0.90	1.30	101.40	0.32
40	33DMP CHX	249.39	0.50	6.50	38.37	0.44	1.50	57.55	0.18
42	23DMP 2MHX	1314.10	2.63	7.00	187.73	2.17	1.50	281.59	0.89
43	3MHX UNK 4	741.65	1.49	7.00	105.95	1.23	1.50	158.92	0.50
431	UNK 4A	0.0	0.0	7.00	0.0	0.0	1.50	0.0	0.0
432	UNK 4B	143.06	0.29	7.00	20.44	0.24	1.50	30.66	0.10
433	UNK 4C	0.0	0.0	7.00	0.0	0.0	1.50	0.0	0.0
44	3EP 224TMP	2181.46	4.37	8.00	272.68	3.16	1.30	354.49	1.12
45	NHP	549.93	1.10	7.00	78.56	0.91	1.51	118.63	0.38
47	MCHX 22DMHX	315.18	0.63	7.50	42.02	0.49	1.60	67.24	0.21
471	UNK 4D	34.13	0.07	8.00	4.27	0.05	1.50	6.40	0.02
48	UNK 5	50.01	0.10	8.00	6.25	0.07	1.50	9.38	0.03
49	223TMP 25DMHX 24DMHX	729.03	1.46	8.00	91.13	1.06	1.50	136.69	0.43
491	UNK 5B	0.0	0.0	8.00	0.0	0.0	1.50	0.0	0.0
492	UNK 5C	0.0	0.0	8.00	0.0	0.0	1.50	0.0	0.0
50	33DMHX 234TMP 233TMP 23DMHX	1710.05	3.43	8.00	213.76	2.47	1.60	342.01	1.08
51	UNK 6	211.09	0.42	8.00	26.39	0.31	1.50	39.58	0.13
52	UNK 7	374.88	0.75	8.00	46.86	0.54	1.50	70.29	0.22
53	3MHP	248.15	0.50	8.00	31.02	0.36	1.63	50.56	0.16
54	225TMHX T12DMCHX	357.19	0.72	8.00	44.65	0.52	1.60	71.44	0.23
541	UNK 9A	11.26	0.02	8.00	1.41	0.02	1.50	2.11	0.01
542	UNK 9B	10.59	0.02	8.00	1.32	0.02	1.50	1.99	0.01
55	NOC	197.97	0.40	8.00	24.74	0.29	1.46	36.12	0.11
56	UNK 10	0.0	0.0	9.00	0.0	0.0	1.50	0.0	0.0
57	UNK 11	29.63	0.06	9.00	3.29	0.04	1.50	4.94	0.02
59	C12DMCHX	17.35	0.03	8.00	2.17	0.03	1.70	3.69	0.01
60	UNK 12	17.46	0.03	9.00	1.94	0.02	1.50	2.91	0.01
61	UNK 13	38.97	0.08	9.00	4.33	0.05	1.50	6.50	0.02
62	UNK 15	33.91	0.07	9.00	3.77	0.04	1.50	5.65	0.02
63	UNK 17	6.53	0.01	9.00	0.73	0.01	1.50	1.09	0.00
64	UNK 18	29.63	0.06	9.00	3.29	0.04	1.50	4.94	0.02
65	UNK 19	79.86	0.16	9.00	8.87	0.10	1.50	13.31	0.04
651	UNK 19A	61.62	0.12	9.00	6.85	0.08	1.50	10.27	0.03
652	UNK 19B	0.0	0.0	9.00	0.0	0.0	1.50	0.0	0.0
66	UNK 20	0.0	0.0	9.00	0.0	0.0	1.50	0.0	0.0
67	UNK 21	36.38	0.07	9.00	4.04	0.05	1.50	6.06	0.02
68	UNK 22	7.70	0.01	9.00	0.30	0.00	1.50	0.45	0.00

TEST OLSON LAB SAMPLE NO 1   YAMAHA 250

PARAFFINS

A

B

PEAK	NAME	PPMC	PCT	CARBON NO	PPM	PCT	REAC. NO.	REACT	PCT
1	METHANE	1067.59	2.41	1.00	1067.59	12.03	0.0	0.0	0.0
2	ETHANE	100.32	0.23	2.00	50.16	0.57	0.42	21.07	0.08
6	PROPANE	15.05	0.03	3.00	5.02	0.06	0.66	3.31	0.01
8	IB	173.77	0.39	4.00	43.44	0.49	1.05	45.62	0.17
10	NB 22DMPR	2052.34	4.63	4.50	456.08	5.14	1.27	579.22	2.17
16	IP	3003.04	6.78	5.00	600.61	6.77	1.66	997.01	3.73
19	NP	1840.98	4.16	5.00	369.20	4.15	1.58	581.75	2.18
25	22DMB	78.70	0.18	6.00	13.12	0.15	1.34	17.58	0.07
28	CP	177.51	0.40	5.00	35.50	0.40	1.56	55.38	0.21
29	23DMB	492.02	1.11	6.00	82.00	0.92	1.86	152.53	0.57
30	2MP	1695.80	3.83	6.00	282.63	3.19	1.59	449.39	1.68
31	3MP	1114.27	2.51	6.00	185.71	2.09	1.64	304.57	1.14
33	NHX	1354.12	3.06	6.00	225.69	2.54	1.58	356.58	1.33
37	MCP 22DMP	958.18	2.16	6.50	147.41	1.66	1.90	280.08	1.05
38	24DMP 223TMB	604.87	1.37	7.00	86.41	0.97	1.30	112.33	0.42
40	33DMP CHX	394.22	0.89	6.50	60.65	0.68	1.50	90.97	0.34
42	23DMP 2MHX	1735.51	3.92	7.00	247.93	2.79	1.50	371.89	1.39
43	3MHX UNK 4	1074.66	2.43	7.00	153.52	1.73	1.50	230.29	0.86
431	UNK 4A	0.0	0.0	7.00	0.0	0.0	1.50	0.0	0.0
432	UNK 4B	246.01	0.56	7.00	35.14	0.40	1.50	52.72	0.20
433	UNK 4C	260.26	0.59	7.00	37.18	0.42	1.50	55.77	0.21
44	3EP 224TMP	824.82	1.86	8.00	103.10	1.16	1.30	134.03	0.50
45	NHP	883.82	1.99	7.00	126.26	1.42	1.51	190.65	0.71
47	MCHX 22DMHX	710.45	1.60	7.50	94.73	1.07	1.60	151.56	0.57
471	UNK 4D	104.26	0.24	8.00	13.03	0.15	1.50	19.55	0.07
48	UNK 5	134.27	0.30	8.00	16.78	0.19	1.50	25.18	0.09
49	223TMP 25DMHX 24DMHX	431.70	0.97	8.00	53.96	0.61	1.50	80.94	0.30
491	UNK 5B	10.10	0.02	8.00	1.25	0.01	1.50	1.89	0.01
492	UNK 5C	29.60	0.07	8.00	3.70	0.04	1.50	5.55	0.02
50	33DMHX 234TMP 233TMP 23DMHX	616.89	1.39	8.00	77.11	0.87	1.60	123.38	0.46
51	UNK 6	137.81	0.31	8.00	17.23	0.19	1.50	25.84	0.10
52	UNK 7	671.25	1.51	8.00	83.91	0.95	1.50	125.86	0.47
53	3MHP	449.59	1.01	8.00	56.20	0.63	1.63	91.60	0.34
54	225TMHX T12DMCHX	196.30	0.44	8.00	24.54	0.28	1.60	39.26	0.15
541	UNK 9A	42.84	0.10	8.00	5.35	0.06	1.50	8.03	0.03
542	UNK 9B	25.46	0.06	8.00	3.18	0.04	1.50	4.77	0.02
55	NOC	454.94	1.03	8.00	56.87	0.64	1.46	83.03	0.31
56	UNK 10	0.0	0.0	9.00	0.0	0.0	1.50	0.0	0.0
57	UNK 11	12.83	0.03	9.00	1.43	0.02	1.50	2.14	0.01
59	C12DMCHX	58.29	0.13	8.00	7.29	0.08	1.70	12.39	0.05
60	UNK 12	58.40	0.13	9.00	6.49	0.07	1.50	9.73	0.04
61	UNK 13	112.35	0.25	9.00	12.48	0.14	1.50	18.72	0.07
62	UNK 15	69.11	0.16	9.00	7.68	0.09	1.50	11.52	0.04
63	UNK 17	17.78	0.04	9.00	1.98	0.02	1.50	2.96	0.01
64	UNK 18	46.17	0.10	9.00	5.13	0.06	1.50	7.70	0.03
65	UNK 19	145.99	0.33	9.00	16.22	0.18	1.50	24.33	0.09
651	UNK 19A	95.17	0.21	9.00	10.57	0.12	1.50	15.86	0.06
652	UNK 19B	0.0	0.0	9.00	0.0	0.0	1.50	0.0	0.0
66	UNK 20	0.0	0.0	9.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

		[illegible]	[illegible]	9.00	10.67	0.18	1.50	24.35	0.09
651	UNK 19A	95.17	0.21	9.00	10.57	0.12	1.50	15.86	0.06
652	UNK 19B	0.0	0.0	9.00	0.0	0.0	1.50	0.0	0.0
66	UNK 20	0.0	0.0	9.00	0.0	0.0	1.50	0.0	0.0
67	UNK 21	43.04	0.10	9.00	4.78	0.05	1.50	7.17	0.03
68	UNK 22	5.56	0.01	9.00	0.62	0.01	1.50	0.93	0.00
69	NN	190.14	0.43	9.00	21.13	0.24	1.42	30.00	0.11
70	UNK 25	50.41	0.11	10.00	5.04	0.06	1.50	7.56	0.03
71	UNK 26	4.04	0.01	10.00	0.40	0.00	1.50	0.61	0.00
72	UNK 28	3.64	0.01	10.00	0.36	0.00	1.50	0.55	0.00
73	UNK 30	7.07	0.02	10.00	0.71	0.01	1.50	1.06	0.00
74	UNK 31	0.0	0.0	10.00	0.0	0.0	1.50	0.0	0.0
75	UNK 32	0.81	0.00	10.00	0.08	0.00	1.50	0.12	0.00
76	UNK 33	39.40	0.09	10.00	3.94	0.04	1.50	5.91	0.02
77	UNK 34	15.36	0.03	10.00	1.54	0.02	1.50	2.30	0.01
78	UNK 35	0.0	0.0	10.00	0.0	0.0	1.50	0.0	0.0
79	ND	88.50	0.20	10.00	8.85	0.10	1.40	12.39	0.05
80	UNK 37	7.58	0.02	11.00	0.69	0.01	1.50	1.03	0.00
81	UNK 38	0.0	0.0	11.00	0.0	0.0	1.50	0.0	0.0
82	UNK 39	0.0	0.0	11.00	0.0	0.0	1.50	0.0	0.0
83	UNK 40	0.0	0.0	11.00	0.0	0.0	1.50	0.0	0.0
84	UNK 41	0.0	0.0	11.00	0.0	0.0	1.50	0.0	0.0
85	OTHER PARAFFINS	5.05	0.01	11.50	0.44	0.00	1.50	0.66	0.00
	TOTAL	25239.91	56.97		5038.97	56.79		6044.73	22.61
	AVERAGE			5.01			1.20		
			Avg C No				AvgR.I.		

TEST OLSON LAB SAMPLE NO 1   YAMAHA 250

TEST OLSON LAB SAMPLE NO 1   YAMAHA 250

OLEFINS

PEAK	NAME	PPMC	PCT	CARBON NO	PPM	PCT	RLAC. NO.	REACT	PCT
3	ETHYLENE	1414.03	3.19	2.00	707.01	7.97	2.88	2036.20	7.62
5	PROPYLENE	801.33	1.81	3.00	267.11	3.01	5.93	1583.96	5.92
7	PROPADIENE	21.05	0.05	3.00	7.02	0.08	3.90	27.36	0.10
9	1B IBE 13B	725.13	1.64	4.00	181.28	2.04	6.04	1094.95	4.10
11	T2B	243.32	0.55	4.00	60.83	0.69	18.98	1154.57	4.32
12	UNK 1	46.93	0.11	4.00	11.73	0.13	15.00	175.99	0.66
13	C2B	126.73	0.29	4.00	31.68	0.36	12.03	381.13	1.43
14	UNK 1A2	1.46	0.00	4.00	0.37	0.00	4.00	1.46	0.01
15	3M1B	73.61	0.17	5.00	14.72	0.17	4.58	67.42	0.25
17	1P	152.39	0.34	5.00	30.48	0.34	3.56	108.50	0.41
18	2M1B	237.13	0.54	5.00	47.43	0.53	5.76	273.18	1.02
20	2M13B	112.55	0.25	5.00	22.51	0.25	6.27	141.13	0.53
21	T2P	238.26	0.54	5.00	47.65	0.54	13.05	621.86	2.33
22	C2P	119.19	0.27	5.00	23.84	0.27	9.15	218.11	0.82
23	2M2B	359.58	0.81	5.00	71.92	0.81	32.20	2315.72	8.66
24	T13P	55.37	0.12	5.00	11.07	0.12	6.80	75.31	0.28
25	UNK 2	9.34	0.02	5.00	1.87	0.02	4.00	7.47	0.03
26	C13P	0.0	0.0	5.00	0.0	0.0	6.80	0.0	0.0
27	CPE	62.58	0.14	5.00	12.52	0.14	38.98	487.84	1.82
28	4M1P	72.70	0.16	6.00	12.12	0.14	3.90	47.26	0.18
29	23DM1B	51.55	0.12	6.00	8.59	0.10	3.73	32.04	0.12
291	UNK 2A2	0.0	0.0	6.00	0.0	0.0	4.00	0.0	0.0
30	4MT2P	116.49	0.26	6.00	19.41	0.22	6.61	128.33	0.48
301	4MC2P	0.0	0.0	6.00	0.0	0.0	6.50	0.0	0.0
31	UNK 3	0.0	0.0	6.00	0.0	0.0	4.00	0.0	0.0
32	2M1P 1HX	239.72	0.54	6.00	39.95	0.45	3.39	135.44	0.51
33	2E1B	13.28	0.03	6.00	2.21	0.02	3.90	8.63	0.03
34	C3HX T3HX T2HX	267.18	0.60	6.00	44.53	0.50	8.40	374.06	1.40
35	2M2P 3MT2P	208.44	0.47	6.00	34.74	0.39	27.12	942.13	3.52
36	23DM13B C2HX	50.76	0.11	6.00	8.46	0.10	20.30	171.73	0.64
37	3MC2P	135.51	0.31	6.00	22.58	0.25	17.00	383.93	1.44
371	UNK 3A2	0.0	[illegible]	6.00	0.0	0.0	25.00	0.0	0.0
38	23DM2B 233TM1B	47.72	0.11	6.50	7.34	0.08	52.90	388.36	1.45
381	UNK 3B2	15.53	0.04	7.00	2.22	0.03	25.00	55.47	0.21
39	1MCPE 34DM1P	0.0	0.0	6.50	0.0	0.0	25.00	0.0	0.0
41	5M1HX	81.82	0.18	7.00	11.69	0.13	2.50	29.22	0.11
411	UNK 3C2	16.66	0.04	7.00	2.38	0.03	2.50	5.95	0.02
42	CHXE	137.53	0.31	6.00	22.92	0.26	5.93	135.93	0.51
43	5MT2HX 34DMC2P 5MC2HX 34DMT2P	39.50	0.09	7.00	5.64	0.06	11.00	62.08	0.23
431	UNK 4A2	0.0	0.0	7.00	0.0	0.0	10.00	0.0	0.0
432	UNK 4B2	0.0	0.0	7.00	0.0	0.0	10.00	0.0	0.0
433	UNK 4C2	15.53	0.04	7.00	2.22	0.03	10.00	22.19	0.08
44	2M1HX 1HP	111.65	0.25	7.00	15.95	0.18	2.80	44.66	0.17
441	UNK 4D2	75.29	0.17	7.00	10.76	0.12	7.00	75.29	0.28
45	2M2HX T3HP C3HP	132.47	0.30	7.00	18.92	0.21	11.30	213.84	0.80

[illegible]	[illegible]	111.65	0.25	7.00	15.95	0.18	2.80	44.66	0.17
441	UNK 4D2	75.29	0.17	7.00	10.76	0.12	7.00	75.29	0.28
45	2M2HX T3HP C3HP	132.47	0.30	7.00	18.92	0.21	11.30	213.84	0.80
451	UNK 4E2	0.0	0.0	7.00	0.0	0.0	10.00	0.0	0.0
46	244TM1P 3E2P T2HP	107.48	0.24	7.33	14.66	0.17	9.40	137.83	0.52
461	UNK 4F2	0.0	0.0	7.00	0.0	0.0	10.00	0.0	0.0
47	23DM2P C2HP	129.32	0.29	7.00	18.47	0.21	47.00	868.26	3.25
471	UNK 4G2	0.0	0.0	7.00	0.0	0.0	30.00	0.0	0.0
48	UNK 5A2	73.04	0.16	7.00	10.43	0.12	30.00	313.04	1.17
49	244TM2P 4MCHXE 3MCHXE	22.51	0.05	7.33	3.07	0.03	13.00	39.92	0.15
491	UNK 5B2	0.0	0.0	7.33	0.0	0.0	13.00	0.0	0.0
492	UNK 5C2	0.0	0.0	7.33	0.0	0.0	13.00	0.0	0.0
51	1MCHXE	33.54	0.08	7.00	4.79	0.05	9.73	46.62	0.17
52	UNK 8	0.0	0.0	8.00	0.0	0.0	7.00	0.0	0.0
53	UNK 9	230.94	0.52	8.00	28.87	0.33	7.00	202.08	0.76
54	10C 2E1HX	102.53	0.23	8.00	12.82	0.14	2.80	35.89	0.13
541	UNK 9A2	71.58	0.16	8.00	8.95	0.10	2.50	22.37	0.08
542	UNK 9B2	72.25	0.16	8.00	9.03	0.10	2.50	22.58	0.08
55	23DM2HX T4OC 2M2HP	88.35	0.20	8.00	11.04	0.12	27.85	307.57	1.15
56	UNK 9C2	0.0	0.0	8.00	0.0	0.0	7.00	0.0	0.0
57	26DM3HP	84.41	0.19	9.00	9.38	0.11	6.59	61.78	0.24
58	T2OC C2OC	0.0	0.0	8.00	0.0	0.0	4.90	0.0	0.0
60	4EECHXE	18.23	0.04	8.00	2.28	0.03	3.05	6.95	0.03
601	UNK 13A2	0.0	0.0	8.00	0.0	0.0	6.00	0.0	0.0
61	UNK 14	16.99	0.04	9.00	1.89	0.02	6.00	11.33	0.04
611	UNK 14A2	0.0	0.0	9.00	0.0	0.0	6.00	0.0	0.0
62	UNK 16	63.59	0.14	9.00	7.07	0.08	6.00	42.39	0.16
621	UNK 16A2	0.0	0.0	9.00	0.0	0.0	6.00	0.0	0.0
631	UNK 17A2	0.0	0.0	9.00	0.0	0.0	6.00	0.0	0.0
65	12DMCHXE	166.68	0.38	8.00	20.84	0.23	15.42	321.28	1.20
651	UNK 19A2	0.0	0.0	9.00	0.0	0.0	6.00	0.0	0.0
67	UNK 21A2	98.70	0.22	9.00	10.97	0.12	6.00	65.80	0.25
68	UNK 23	72.14	0.16	9.00	8.02	0.09	6.00	48.09	0.18
69	UNK 24	180.75	0.41	9.00	20.08	0.23	6.00	120.50	0.45
691	UNK 24A2	0.0	0.0	10.00	0.0	0.0	6.00	0.0	0.0
71	UNK 27	41.98	0.09	10.00	4.20	0.05	6.00	25.19	0.09
711	UNK 27A2	0.0	0.0	10.00	0.0	0.0	6.00	0.0	0.0
72	UNK 29	74.51	0.17	10.00	7.45	0.08	6.00	44.70	0.17
721	UNK 29A2	18.46	0.04	10.00	1.85	0.02	6.00	11.07	0.04
741	UNK 31A2	0.0	0.0	10.00	0.0	0.0	6.00	0.0	0.0
85	OTHER OLEFINS	0.0	0.0	11.00	0.0	0.0	6.00	0.0	0.0
	TOTAL	8397.21	18.95		2059.82	23.21		*******	62.78
	AVERAGE			4.08			8.15	~~16785.97~~ 16785.9	

TEST OLSON LAB SAMPLE NO 1 YAMAHA 250

TEST OLSON LAB SAMPLE NO 1 YAMAHA 250

AROMATICS

PEAK	NAME	PPMC	PCT	CARBON NO	PPM	PCT	REAC. NO.	REACT	PCT
39	BZ	964.26	2.18	6.00	160.71	1.81	0.56	90.00	0.34
50	TOL	2310.61	5.21	7.00	330.09	3.72	2.20	726.19	2.72
63	EBZ	518.88	1.17	8.00	64.86	0.73	2.03	131.67	0.49
64	PX MX	2033.11	4.59	8.00	254.14	2.86	4.92	1250.36	4.68
652	PHEE (STYRENE)	0.0	0.0	9.00	0.0	0.0	3.50	0.0	0.0
66	OX	941.72	2.13	8.00	117.72	1.31	3.64	428.68	1.60
70	IPRBZ	3.19	0.01	9.00	0.35	0.00	1.64	0.58	0.00
73	NPRBZ	184.35	0.42	9.00	20.48	0.23	1.70	34.82	0.13
74	1M3EBZ 1M4EBZ	703.23	1.59	9.00	78.14	0.88	4.10	320.36	1.20
75	135TMBZ	294.08	0.66	9.00	32.69	0.37	8.64	282.31	1.06
751	UNK 32A3	0.0	0.0	10.00	0.0	0.0	6.00	0.0	0.0
76	1M2EBZ 2PH1PR	333.09	0.75	9.00	37.01	0.42	3.40	125.83	0.47
761	UNK 33A3	56.20	0.13	10.00	5.62	0.06	6.00	33.72	0.13
77	C1PH1PR TBBZ 124TMBZ	799.47	1.80	9.33	85.69	0.97	3.20	274.20	1.03
78	IBBZ SBBZ	25.32	0.06	10.00	2.53	0.03	1.00	2.53	0.01
79	UNK 36	24.70	0.06	9.50	2.60	0.03	5.00	13.00	0.05
80	1M3IPRBZ 123TMBZ	112.20	0.25	9.50	11.81	0.13	5.80	68.50	0.26
81	1M4IPRBZ T1PH1PR	63.61	0.14	9.50	6.70	0.08	3.00	20.09	0.08
82	1M2IPRBZ	23.06	0.05	10.00	2.31	0.03	2.90	6.69	0.03
83	13DEBZ 1M3NPRBZ	122.90	0.28	10.00	12.29	0.14	4.20	51.62	0.19
84	1M4NPRBZ NBBZ 12DEBZ 13DM5EBZ 14DEBZ	65.77	0.15	10.00	6.58	0.07	3.40	22.36	0.08
85	OTHER AROMATICS	0.0	0.0	11.00	0.0	0.0	5.00	0.0	0.0
	TOTAL	9579.73	21.62		1232.29	13.99		3883.32	14.52
	AVERAGE			7.77			3.15		

ACETYLENES

PEAK	NAME	PPMC	PCT	CARBON NO	PPM	PCT	REAC. NO.	REACT	PCT
4	ACETYLENE	1072.43	2.42	2.00	536.22	6.04	0.0	0.0	0.0
107	MA	17.91	0.04	3.00	5.97	0.07	3.90	23.28	0.09
13	EA WITH C2B	0.0	0.0	4.00	0.0	0.0	18.78	0.0	0.0
	TOTAL	1090.34	2.46		542.18	6.11		23.28	0.09
	AVERAGE			2.01			0.04		

	PPMC	PPM	REACTIVITY
GRAND TOTALS	******** 44307.07	8873.133	******** 26737.24
AS HEXANE	7384.523		26737.24

MAGA INDEX 0.625
GM INDEX 3.013
AVE. C NUMBER 4.993